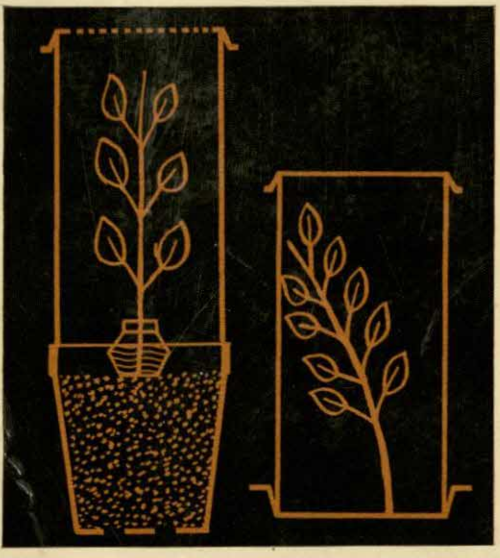
Nuffield Junior Science

Animals and Plants



A Source Book of Information and Ideas

Collins

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STATE INSTITUTE OF EDUCATION
Govt. of West Bengal.

Nuffield Junior Science

Teacher's Guide 1
Teacher's Guide 2
Apparatus: A Source Book of Information and Ideas
Animals and Plants: A Source Book of Information and Ideas

Teacher's Background Booklets:
  Autumn into Winter
  Science and History
  Mammals in Classrooms

Nuffield Junior Science

Animals and Plants

A Source Book of Information and Ideas

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Foreword

It is appropriate that the second group of books to be produced by the Nuffield Foundation Science Teaching Project should be designed to help in the primary schools. For the emphasis on enquiry and involvement which is characteristic of 'Nuffield Science' is also a feature of the approach which many primary schools have adopted with striking success. The books produced by the Nuffield Junior Science team will, we hope, suggest topics and methods to many teachers who are interested in the contribution which science can make to the education of younger boys and girls.

The Junior Science, like the other Nuffield courses, has many parents. Practising teachers (particularly, of course, the members of the Junior Science team), the Consultative Committee, and the Schools Council have all played a large part; and a particular feature of this project is that the Local Education Authorities concerned in the trials of the material have set up science centres—a move which should have far-reaching results in encouraging local initiative in curriculum development. In a number of areas, the trials have been conducted simultaneously with the trials of the Nuffield Junior Mathematics Project, and this has provided a useful link between the two activities.

It is even more true of the Junior Science than it was of the Nuffield 'O' level Science that the process of helping teachers with new courses is a large and continuing one. A beginning has been made, and the Schools Council (with the cooperation and support of the Foundation) is taking responsibility for the next stage. These books are therefore the first fruits of what will be a larger harvest.

Brian Young
Director of the Nuffield Foundation

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‘Children are people. They grow into
tomorrow only as they live today.’

JOHN DEWEY

Introduction

THE CHILD'S SURROUNDINGS are the starting points for his education, and in a rich environment there will be much to arouse his curiosity. For example, by growing plants in a school garden or by introducing them into a classroom the teacher will have an increased opportunity to stimulate interests that give rise to purposeful exploration and learning.

Teachers who have kept living animals and plants in their classrooms and laboratories know what a tremendous effect this can have on children, who acquire firsthand experience which helps to develop their understanding of animal and plant life. They are often stimulated to talk, ask questions, and express their thoughts and feelings through painting, modelling, or writing. Animals and plants can be first-rate starting points for all kinds of investigation in science, geography, history, and mathematics. Children can be encouraged to develop a responsible, sensitive attitude towards other living creatures.

We sometimes worry lest the 'rich environment' causes children to gather a great range of apparently unrelated experience and knowledge. There are, of course, patterns to animal and plant life which make sense of this bewildering diversity. As teachers, we can play a more effective role in the classroom when we know something of these patterns, because this enables us to provide our pupils with a suitable breadth of experience from which, at some stage and with our help, they may come to an understanding of them.

To help teachers give their pupils some of this firsthand experience of animal and plant life we have produced this volume which is a combination of handbook, textbook, and guide to the relevant literature. It contains:

Information about the outstanding features and habits of some animals and plants

Advice on the care and management of these animals and plants in schools

Suggestions for some educational possibilities

Sources of information, materials, and specimens.

We have been selective in our choice of animals and plants, including some familiar classroom animals such as hamsters, guinea pigs, and stick insects, and less familiar ones such as gerbils and tropical silkmoths. In dealing with plants we have had in mind the poor conditions for plant growth that exist in some classrooms, and have indicated what might be grown there. There are also suggestions to help and encourage those who are fortunate enough to have gardens or greenhouses attached to their schools. Keeping in mind the needs of the teacher who has no specialist knowledge of biology, we have tried to reduce scientific terminology to a minimum.

Above all, this is a book to help teachers to come to know about and care for living things. It is a book about animals and plants.

Part One: Animals

Chapter 1

Mammals

Introduction

MAMMALS are perhaps the most popular of all types of animal kept in school. They are, of course, most closely related to ourselves, and for that reason much can be learnt from them. The life cycles of the small mammals commonly kept in schools are short. Children can witness mating, pregnancy, and birth, and the whole process of development in a relatively small amount of time. Children soon become aware of how parent mammals care for their young, for example by suckling them. Interesting differences among mammals soon become apparent. The young guinea pig is born with fur developed, eyes and ears open, and can run about the cage and take solid food a few hours after birth, while the baby rat is naked and blind at birth, and much more dependent on its mother. Rabbits and guinea pigs crop and crunch their food and prefer lots of fresh greens and hay, while rodents, such as mice, rats, and hamsters, gnaw at harder foods such as grain, besides eating small quantities of greens.

Some mammals which originally lived in desert regions are now kept in captivity. The hamster is the best known but the various species of gerbil becoming available open up an interesting new world. These animals drink very little, produce very small quantities of urine and hard, dry droppings, and live predominantly on a diet of grain. In the desert they live in burrows during the day and emerge at night, or when temperatures are lower and the air is less dry. They live well in captivity. Some become diurnal, and all are easy to handle, feed, and rear. (See pages 50-58).

The Teacher's Background Booklet, *Mammals in Classrooms*, deals much more fully with the educational possibilities arising out of keeping small mammals in the classroom. Our purpose here is to concentrate on the practical problems involved. Our aim is to encourage more teachers to take up this rewarding work.

Sources of supply

COLLECTING

The rearing of wild mammals in captivity is best left to experts who are aware of the problems involved and can devote a considerable amount of time to the task. Almost all wild mammals have a tendency to flee or hide when approached by man; many of them bite when cornered. The bites may not be painful, and persons accustomed to dealing with these mammals expect to be bitten. The beginner, taken by surprise, is quite likely to release the animal or handle it nervously. Wild mammals become tense when captured and may not adapt themselves to captivity. With expert handling and treatment, animals may adapt completely to man's presence and grow tame. They may even thrive in captivity. With anything less than expert care, wild mammals are not likely to settle down in captivity: the keeper gains little insight into their normal behaviour, and the animals soon die.

Wild mammals invariably harbour a population of bacteria, and often parasitic worms, fleas, and lice. Many of these organisms do not cause disease in humans and do little or no apparent harm to their hosts. But there is a small risk of infection. It is not widely realized, for instance, that hedgehogs in urban surroundings visit rubbish dumps in search of insect food and may carry several types of bacteria harmful to humans. In gardens, the hedgehog's appetite for insects, slugs, and other small creatures is useful. This is much the best place to keep the animal in captivity. Even though hedgehogs are easily tamed, we would not advise teachers and children to handle them. We suggest that teachers think twice before introducing any species of wild mammal into the classroom.

PURCHASING

When buying a mammal it is important to know if it is healthy. Expert advice is available to help the teacher to buy wisely. The Medical Research Council issue a list of accredited breeders of mammals and carry out regular checks of breeding stock. There is always the possibility of an infection developing in a large animal house where hundreds or thousands of mammals are bred. When this happens the breeder's name is struck off the list until the infection disappears. Reputable breeders are very willing to cooperate in this scheme since it is to their own advantage to guarantee high standards of animal care and management throughout the country.

There is a slight risk that an infected mammal will transmit the infection to a human. Teachers will want to take every reasonable precaution to prevent this from happening to children in school. We advise them to obtain mammals from accredited sources only.

The current list of accredited mammal breeders can be obtained from Mrs M. Bardell, Medical Research Council, Laboratory Animals Centre, Woodmansterne Road, Carshalton, Surrey.

TRANSPORTING

If animals cannot be purchased locally, the teacher ordering them should name the nearest railway station with a passenger train service to ensure there is no doubt as to the destination of the animals. Small mammals are usually sent by passenger train since this is faster than freight service. The supplier usually states when the animals will be despatched, and one can generally arrange for the local station to inform the school when the animals arrive. Animals may arrive at the station after the parcels delivery vans have gone off on their rounds, in which case the teacher may collect the animals personally. Teachers should try to ensure that the mammals are not exposed to very high or very low temperatures, and that they are removed from their travelling boxes as soon as possible.

If the mammals are obtained locally and transported only a short distance a simple travelling box can be used. A cardboard box is adequate, provided it is escape-proof. Ventilation holes are necessary, particularly if the box is a small one. Shredded paper or wood wool placed inside the box give the animal something to burrow into and help to prevent it from being thrown about.

Should the teacher be responsible for sending mammals on a journey of several hours' duration he will need to provide a strong box of wood, stout cardboard, hardboard, or metal. Ventilation holes of about 3 x 2 in. should be cut in the ends of the box and covered on the inside with perforated zinc. This must be securely attached with at least half-an-inch overlap all round so that there are no exposed edges of wood or cardboard on which the mammal can take hold with its teeth. A layer of dry sawdust in the bottom of the box will absorb urine and insulate the box, should it be placed on a cold floor. Wood wool or paper wool can be packed inside the box. Air passes readily through them and animals can burrow without danger of suffocation. Dry food such as grain or pellets should be supplied for rats, mice, hamsters, lemmings, and gerbils. Rabbits and guinea pigs should have a supply of hay. It is impractical to provide water in pots or bottles, but the need for moisture can be met with carrots or pieces of apple and similar moist vegetables. These must never be omitted, even for the desert-living mammals. If the animals are to be sent via public transport the box should be prominently labelled: LIVESTOCK, KEEP AWAY FROM HEATED PIPES AND DRAUGHTS, LEAVE AMPLE AIR SPACE. Avoid despatching animals over the weekend and inform the recipient in good time of the date of despatch.

DEALING WITH NEW ARRIVALS

The mammals are almost bound to be frightened and shocked by the journey. The teacher's aim should be to install them in their permanent quarters immediately with a minimum of fuss or disturbance. The cages should be set up before the travelling box is opened. Resist the temptation to 'have a look' or exhibit the new arrivals and concentrate on quietly transferring them to their new home. Leave them to settle down overnight. Water, appropriate food, bedding, and nesting material should all be provided. If the mammals have been properly housed on the journey they should not be injured, but the teacher should check for obvious signs of physical distress. If he suspects an injury, he should take the animal to a veterinary surgeon.

SPECIES FOR THE BEGINNER TO KEEP

Taking into account availability, cost, ease of management, and attractiveness, we would advise beginners to start with the golden hamster (page 50). Next we suggest the rat (page 64), followed by the guinea pig, mouse, and rabbit. Two species of gerbil, the Mongolian gerbil and *Meriones libycus*, as well as the steppe lemming may well be the most suitable for keeping in schools, but they are not widely available. Supplies are restricted and prices are fairly high, but they are strongly recommended, nevertheless.

At the other end of the scale, we do not advise schools to attempt to keep any species of monkey. Mammals such as bushbabies have specialized requirements and need a great deal of care and attention. Various species of ground squirrel, for example, the chipmunk, are now available. Although they make attractive pets, they are highly active animals and need very large cages. They are not very suitable for schools. Small carnivores, such as ferrets and polecats, are not good for beginners.

Management in captivity

GENERAL HYGIENE

After handling mammals, one should wash one's hands, especially before touching food. It is wise to establish a routine of handwashing after handling. Some children quite unconsciously suck their fingers or touch their mouth and face. Disinfectant soaps such as Hycolin are strongly recommended. The risk of an infection developing from contact with classroom mammals is very slight, if everyone practises good hygiene. Infection is a two-way process. For the mammals' sake, as well, the teacher should ensure that no one handles the animals with dirty hands.

HANDLING

Time, patience, and firm but gentle treatment are necessary for securing an animal's confidence. Nothing will be gained from forcing an unwilling animal into close contact with humans. Wild mammals have an instinctive flight urge. Mammals reared in captivity inherit the instinct, but can rapidly adapt to man's presence. They are called 'tame' when they show no tendency to run away from man. Certain species, such as the albino rat, have been selectively bred in laboratories for many years. These laboratory animals are much more docile than their wild counterparts. Other species, such as the gerbils, show little or no tendency to bite humans, and come forward to explore a human hand just like any other object placed in their cage. Regular handling is a necessary part of the taming process. If animals are handled correctly to ensure that there is no physical discomfort for them, they can establish good relations with their keepers.

Whatever the species chosen, it is best to start with young mammals just past weaning, since they rapidly become used to handling at this age. Hamsters, mice, gerbils, lemmings, and young rats can all be handled by cupping both hands around the animal and scooping it up. This two-handed method, shown in figure 1, is best for children, since it is so easy to learn. Adult rats, guinea pigs, and rabbits are somewhat larger and require a slightly different grip. Details of handling techniques are included in the notes on each species later on in this chapter. The 'scoop' method is undoubtedly best for general purposes (see figure 1).

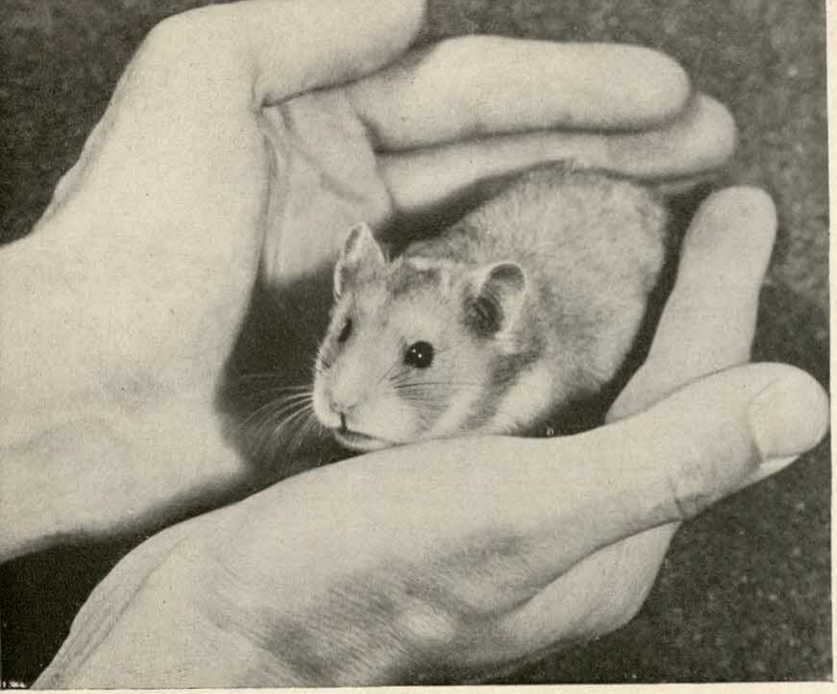

Fig. 1. Picking up a hamster by the scoop method.

TERRITORY AND COMPATIBILITY

Different species of mammal should be housed in separate cages. Adult strangers should generally not be left together unattended. Individuals differing markedly in size should be separated, except that a mother should be left undisturbed with her young.

It is interesting to examine the zoological background for these rule-of-thumb procedures. Mammals in the wild do not naturally wander anywhere at will. Apart from geographical and climatic restrictions, mammals are usually confined to a territory. This is an area, large or small, which the individual defends against intrusion by others of the same species. Within this territory the area most strongly defended is the 'home', retreat or burrow. The animal moves along certain pathways within the territory and may mark the boundaries with scent or urine signals. The golden hamster is strongly territorial. Certain species, such as rabbits, live communally. Territorial behaviour is still present in this latter case. The unit, however, is not a single individual but the larger social group comprising the herd or warren. Territorial aggressiveness is displayed by members of this larger unit against individuals from another unit. When adults of opposite sex come together and mate, they become a single unit with a common territory. Their liaison may be temporary or for life. When the young are born they are part of the same territorial unit as the mother. If the father does not share their territory he is fought by the female whenever he approaches the nest of young. Eventually, the mother-young unit breaks up and the young disperse to set up new territories, each defended against parents, litter mates, and others of the same species. Hediger (1950) gives a more detailed account of territorial behaviours, but we hope the simplified version given above will provide a helpful short guide.

The cage, of necessity, becomes the territory, though quite different in shape and size from that of the wild species. One part is usually made into a home or nest where the mammal has greater relative security. The practice of providing nesting material enables the mammal to construct its own nest, which becomes its retreat where it immediately returns when disturbed. Other parts of the cage may be used for urination, but the nest is never soiled by urine or faeces. If an adult stranger is introduced into a cage containing an established animal, they will fight or display aggressive behaviour depending on the species and on individual variation. This behaviour is affected by two instincts related to reproduction: the urge to mate and the maternal instinct. For example, if an adult female hamster is placed in a male's cage, the pair will either fight or mate, depending on the female's sexual condition. The female hamster comes on heat once every four days, usually in the evening. Only at this time will she accept the male as a mate. At all other times she will almost certainly fight and possibly kill him. She may even fight after mating. The female cannot be described as fickle since her behaviour appears to be automatic and governed by hormones circulating in her bloodstream. Gerbils show similar behaviour patterns, though the fights are less vicious. Mice, rats, and guinea pigs, in that order, show less and less territorial aggression; an animal occupying a cage does not have a marked advantage in combat with an intruder. In the wild state these animals lead communal lives. Cases of several litters of mice sharing the same nest are common (Matthews 1952). The laboratory-bred animals seldom engage in serious fights.

Aggressive species like the hamster may be housed in colonies if placed together while they are young. It is common practice to assemble groups of animals of one sex in large cages at three or four weeks of age. A male and female placed together at this time can often be left in the same cage for life, though if they fight when very young babies are in the nest it is sensible to confine the male to another part of the cage by inserting a temporary partition.

HEAT AND LIGHT REQUIREMENTS OF SMALL MAMMALS

Normal room temperature conditions (16-21°C) are suitable for all the mammals listed on page 16. Fluctuations above and below this range are unavoidable in most schools, but the effects of these temperature changes can be reduced. In cold weather, extra supplies of nesting material such as shredded paper or wood wool can be supplied. In addition, on a very cold night, the cage can be wrapped in sacking or covered with layers of corrugated cardboard. Care must be taken to see that there is adequate ventilation. During hot weather the cage should be kept in the coolest part of the room. It must never be left exposed to hot sunlight for long periods. The cage should not be placed close to convector heaters which blow out streams of hot air. Short exposure to sunlight is beneficial since it promotes vitamin D formation, essential for healthy bone growth. Composition pellet diets (page 21) also contain small amounts of this vitamin as do milk and fish-liver oils.

Some part of the cage should provide the mammals with seclusion. This is especially necessary for nocturnal mammals. Nesting material is adequate for this purpose and there is no need to provide darkened nesting boxes, although it is interesting to observe the mammals' reactions when such a box is provided.

CAGE SITUATION

When large numbers of mammals are to be kept, they should be housed in a separate room and brought into the classroom when required. This arrangement can be very useful in schools where it is convenient to have a central store for food, bedding, and cleaning materials. A draughty place is not a good site for a cage since the animals will very likely catch cold. It may be necessary to exclude draughts from open-mesh cages by fitting a temporary covering of hardboard or cardboard at night. Most mammals accommodate themselves to moderate changes in temperature but extremes must be avoided. Full summer sun shining through a south facing window may be just as dangerous as a night frost in an unheated outhouse. The cage should be kept off the floor where there is a greater chance of contact with dust, dirt, and wild rats or mice. Mammals must not be housed in a room known to be infested with wild rats or mice since there is a chance that captive animals will be contaminated.

FOOD

For healthy growth, all mammals require a diet containing adequate amounts of protein, carbohydrate, and fats, together with smaller amounts of vitamins and mineral salts. Some teachers prefer to use a composition diet in pellet form known to contain all these vital substances in suitable proportions. One type of food pellet suitable for mice, rats, hamsters, gerbils, and lemmings is called Diet 41B. Another, suitable for guinea pigs and rabbits, is known as Diet SG1. Small quantities are relatively expensive, 11s 6d per 14 lb, plus carriage, but ½-cwt bags, which cost about £2 plus carriage, are no more expensive than other types of food.

These diets can be obtained from the Scientific Animal Service Home Farm, Aldenham Park, Elstree, Herts., from Pilsbury's Ltd., 21 Priory Road, Edgbaston, Birmingham 5, or from Philip Harris Ltd., Ludgate Hill, Birmingham 3.

Although the pellet diets supply all the nutritional requirements there is no reason why children should not, in addition, give a mammal fresh milk and raw vegetables. Indeed, this is strongly recommended since animals seem to enjoy a varied diet. Guinea pigs and rabbits will also benefit from meadow hay but it must be of good quality. Mouldy hay must not be given to mammals since it sometimes contains the substance dicoumarol which can kill small mammals by causing the breakdown of the minute blood vessels throughout the body. Hay can be bought from reliable suppliers of animal foods.

It is by no means essential to use pellet foods. Small rodents thrive on a diet of mixed grain including the seeds of wheat, sunflower, maize, and rolled oats, if this is supplemented with fresh greens and root vegetables and an occasional drink of milk. Uneaten fresh food and milk should be removed at the end of the day. A little care is advisable in buying grain from pet shops. We would advise teachers not to buy grain and other animal foods from dealers who store them in open bins or sacks, since contamination by wild rats or mice is always a possibility. For the same reason, dry animal foods should be stored in tins with well fitting lids and any spilt food should be swept up and thrown away, preferably not into an open wastepaper basket, but into a dustbin with a proper lid.

It is advisable to provide rats, mice, hamsters, and gerbils with wood to chew. This is not a dietary requirement, but gnawing a hard surface enables the animal to wear down the tips of the chisel-shaped incisor teeth. These grow throughout life and may become over-long without sufficient work to do. A cotton reel is excellent.

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WATER

An adequate supply of clean water is essential. Desert-living species such as hamsters, gerbils, and lemmings drink very little, but a water bottle is still necessary, since conditions in a centrally heated building can be hot and dry. The section on water containers (p. [illegible]) gives details of suitable receptacles.

BEDDING AND NESTING MATERIALS

Bedding is the material strewn over the floor of the cage with the object of absorbing urine and drying out faeces. Nesting materials are fashioned by the mammal into a nest or shelter.

One of the objections to keeping mammals in the classroom is the smell produced by the decomposition of faeces and urine. Large mammals excrete greater quantities than small mammals. If possible, guinea pigs and rabbits should be kept out of doors. Gerbils and lemmings produce minute quantities of urine and dry, hard faeces; both are adaptations to the desert habitat. Teachers need have no fear of obnoxious odours developing even when these animals are kept in a small room. Hamsters produce a little more urine and a slight odour develops after about a week. Rats and mice need careful attention if their cages are to remain sweet-smelling and clean.

Sawdust is the commonest bedding material since it is cheap and readily obtained. It is not very absorbent and should be changed once a week for hamsters and possibly twice a week for rats, mice, guinea pigs, and rabbits. Softwood sawdust should be used in preference to that obtained from hardwoods, since the latter is sometimes impregnated with substances which might be harmful to the animals. Sawdust which has remained on a workshop or shed floor for long periods may be fouled by dogs, cats, or wild rodents and must not be used for bedding.

Vermiculite is a highly absorbent, non-toxic material manufactured from mica. It is used in the building industry as an insulator (not to be confused with polystyrene which absorbs very little water) and by horticulturists as a medium for propagating plants from cuttings. It can be used to advantage as a bedding material in trays beneath mesh floored cages but it may not be so suitable in solid floored cages. One breeder, to our knowledge, has found that hamsters have difficulty in removing the flakes of Vermiculite from their cheek pouches. He believes that this may cause inflammation.

Sterolit is a commercially produced granular bedding material which has found favour in this country. It is sterile and highly absorbent, and does not pack down into a solid mass when wet. It contains deodorant and germicidal substances which do not harm the animals. It can be used either in solid or mesh bottomed cages. It is more expensive than sawdust, costing about £2 per 50 lb bag, plus carriage. The extra cost, however, is partly offset by the fact that cages need cleaning less frequently. In practice we have found that odours are reduced but not eliminated entirely. The frequency of cage cleaning is often determined by what one's nose can tolerate. We would not recommend anyone with a sensitive nose to keep mice, Sterolit or no Sterolit! Perhaps Sterolit is of greatest use when large numbers of mammals are kept since it does reduce the frequency of cage cleaning.

Dry peat is another material used as bedding. It has a high acid content which delays decomposition of faeces. We found it particularly suitable for trays beneath mesh floored cages. In solid floored cages it tends to be too dusty.

The best nesting materials are shredded paper, wood wool, and wood shavings. White, shredded paper, such as that obtainable from a confectioner, is better than shredded newspaper. Clean softwood shavings are quite acceptable. Clean, dry meadow hay is a suitable nesting material for guinea pigs, which must, in any case, be supplied as part of the diet. Hamsters have the habit of stuffing nesting material into their cheek pouches; their nesting material should not contain hard, sharply pointed materials such as the stalks of coarse grasses sometimes found in hay.

It is important to use clean bedding and nesting materials from a reliable source. Dirty, dusty materials might be a source of infection and must not be used.

CARE AND CLEANING

Regular and careful cage cleaning is necessary to ensure the health of both the animal and those tending it. The urine and faeces of a diseased mammal are a potential source of infection to other mammals and to humans. There is little point in paying extra for good quality, healthy mammals, if they are not kept in clean conditions. Although the health risk is slight, we strongly advise teachers to follow the simple routine described below. There is a positive aspect to cage cleaning, since it is not just a chore, but part of the responsibility we assume for a captive animal. This involves all aspects of the animal's existence. Here, too, there is a fine opportunity for children to gain experience of good hygiene practice, which, one hopes, will carry over into their everyday lives.

Another reason for cleaning cages is to control smells. Some scents in urine and secretions of the sex glands are used to demarcate territory (see page 18) and are also an aid to recognition. When an animal is transferred to a clean cage it marks it with its own personal smell. The smell will be stronger if the cage has not been properly cleaned and there is any trace of a smell left behind by a previous occupant (Lane-Petter 1963). Thoroughness, in cage cleaning, is even more important than frequency, for controlling smells. Neither man nor animal gains anything from the odours released by decomposing urine and faeces. These are much more objectionable and should not be tolerated. Cages which have inaccessible corners and those made from absorbent material such as untreated wood are more difficult to clean properly.

It is sensible to use well designed cages and to clean them thoroughly at intervals suggested by one's own nose. Too frequent cleaning does more harm than good. It upsets the animals and stimulates a greater production of scent. Inadequate cleaning inevitably causes ammoniacal odours from the decaying waste. Once-weekly cleaning is about right for most small mammals.

Disinfectants

The hypochlorites such as Milton are cheap and convenient but they irritate skin and mucous membranes and eventually corrode metal. They are most useful in disinfecting bottles and glassware. Chlorine household solutions are similar in action to the hypochlorites and usually contain 1 per cent chlorine. The directions for use should be followed carefully. A concentration of one part chlorine to 10,000 parts water is satisfactory for most purposes. If the neat liquid is spilt on the skin it should be washed off immediately with water.

The chloroxylenols such as Dettol are safe to handle. These are probably the most satisfactory for school use. A concentration of one part chloroxylenol to 40 parts water is sufficient for general swabbing. Sodium carbonate—washing soda—is a cheap and useful disinfectant. It is commonly employed in disinfection following an outbreak of foot and mouth disease. A 4 per cent solution in hot water is useful for general cleansing.

Strong disinfectants such as Lysol, the cresols, and phenol, are corrosive to the skin and we do not advise their use in classrooms.

A very effective, non-corrosive disinfectant is Cetavlon (Cetrimide BP 20 per cent w/v). A dilution of 3 tablespoonfuls of Cetavlon to one pint of water is suitable. Cetavlon, however, is expensive.

Cleaning routine

During cleaning, animals should be transferred to a spare cage or put in the care of a child. The soiled bedding is then scraped out on a sheet of newspaper, using a paint scraper or similar tool. There is no need to throw away the animal's nest since this is seldom fouled. If the nest contains young animals the whole of it should be carefully moved to the clean cage, otherwise the young may become chilled while the parents rearrange nesting material and make a new nest. This can retard their growth. Regular cleaning should be suspended while the offspring are very young. As a general rule, cleaning may be resumed when the young are old enough to leave the nest of their own accord.

Having scraped out most of the bedding, scrub the cage vigorously with a hard brush and hot water containing a detergent. This is essential to loosen and remove waste material and faeces which stick to cracks and corners. Plastic box-type cages have rounded corners and smooth internal surfaces and are very easy to clean. After washing the cage, scrub it again with water containing a disinfectant or preferably immerse in a suitable disinfectant. It is sometimes impossible to immerse the whole of a cage at once, but the same result is achieved by submerging one side at a time. Cages should be left to soak for at least 5-10 minutes.

The cage should be allowed to dry before fresh bedding is introduced. If the cage is of simple design, this cleaning routine is quick and thorough. Food and water containers should be washed and disinfected when the cage is cleaned. It is useful to have a spare set of food containers and water bottles and use them alternately, changing about twice a week.

Disposal of dirty bedding

Dirty bedding should be wrapped in newspaper and either burnt or placed in a dustbin out of doors. It must not be left in an open-top waste box in the classroom. Sterolit does not burn and cannot be disposed of in this way unless incinerated with quantities of burnable materials. Soiled peat bedding can be buried in the ground where it will decay to form a useful compost.

Rubber gloves

Many people prefer to wear rubber gloves when cleaning out cages. This does not remove the need to wash the hands thoroughly when the operation is complete.

TABLE 1 A summary of breeding characteristics of mammals suitable for keeping in schools

Species	Age of maturation		Suggested minimum breeding age	Usual maximum breeding age	Average length of gestation	Usual litter size	Desirable weaning		Normal life span
	Males	Females					Age	Weight	
Golden hamster (*Mesocricetus auratus*)	8 weeks	6 weeks	10-12 weeks	12 months	16 days	5-7	21 days	40 g	1-1½ years
Mongolian gerbil (*Meriones unguiculatus*)	9-12 weeks	9-12 weeks	3 months	18 months	25 days	4-6	21 days	12-15 g	3 years+
Gerbil (*Meriones libycus*)	3 mths	3 months	3-4 months	18 months	22 days	4-6	30 days	45 g	3 years+
Steppe lemming (*Lagurus lagurus*)	4 weeks	4 weeks	6 weeks	12 months	19-20 days	4-6	21 days	7 g	1½ years
Mouse (*Mus musculus domesticus*)	6 weeks	6 weeks	10 weeks	12 months	19-21 days	8-11	21 days	10-12 g	1-1½ years
Rat (*Rattus norvegicus*)	4 weeks	6-8 weeks	10-11 weeks	12-15 months	20-22 days	9-11	22 days	35-40 g	2-3 years
Guinea pig (*Cavia porcellus*)	10 weeks	4 weeks	4-6 months	18-24 months	63-72 days	3-4	14 days	160-180 g	2-3 years
Rabbit (*Oryctolagus cuniculus*) (small varieties)	4-6 mths	4-6 months	6 months	24 months	30 days	4-6	56 days	1,000 g	4-5 years

BREEDING SMALL MAMMALS IN CAPTIVITY

Table 1 (page 26) contains a summary of the breeding characteristics of a number of mammals.

Further information is given in the sections dealing with particular species, pages 50-76. Some of the books included in the bibliography also contain detailed accounts of breeding which will be useful for those wishing to rear one particular species.

There are good educational reasons for letting small mammals breed in the classroom, as mentioned earlier. We advise teachers to plan a breeding programme rather than keep adult mammals together and just wait. The children can gather a richer fund of experience if a litter is born and weaned during term time. They can then see the period of most rapid development of the mammal and observe how mammals care for their young. Depending on the species, it may or may not be possible for the children to witness mating and the accompanying sexual display, if any. Hamsters, for instance, seldom mate at any other time than late evening from about seven o'clock onwards.

Of course, it is up to the teacher to decide on the amount and depth of explanation appropriate to a particular group of children. Clearly this depends on their age, their previous experience, and their interest. We believe it is not to the children's best advantage either to 'wrap up the sex' or to reveal all with scientific detachment. Perhaps by observing mammalian reproduction and parental care, the children will eventually develop a proper regard for the same processes in the human species, where they are associated with marriage, family life, responsibility, and love. The teacher can but try to adjust his explanations and responses appropriately.

AILMENTS

As a general rule, teachers should take mammals with suspected ailments to the veterinary surgeon. There are a few ailments which the teacher can deal with himself, but most require skilled diagnosis and treatment which are outside the teacher's province.

When a mammal develops an ailment, or breaks a limb, the mammal's behaviour changes. It is usually difficult to identify the cause of such a change. We advise against ambitious amateur medication. But if the mammal's normal pattern of behaviour is closely observed, the teacher is much more likely to realize when the animal is not well.

Some of the changes to look out for are: loss of appetite, listlessness, diarrhoea, dull eyes, discharge from eyes, nose, ears, or anus; frequent scratching of one part of the body, coughing, sneezing, or wheezing, abnormal gait or posture.

Prevention is much easier than cure. Summarizing the advice given in this chapter, we suggest that the following principles of care and management be observed:

1. Obtain mammals from a reliable source.
2. House them in suitable caging.
3. Isolate the captive mammals from direct or indirect contact with wild animals and from domestic dogs and cats.
4. Clean and disinfect cages and feeding utensils regularly.
5. Supply clean food, bedding, water, and nesting materials, and pieces of wood to gnaw.
6. Handle the mammals regularly and sympathetically, but always with clean hands. Learn the normal pattern of behaviour and watch out for changes.
7. Wash the hands after handling a mammal.

If the teacher feels that these principles are too elaborate, then we suggest it is better not to keep mammals at all.

EUTHANASIA (HUMANE KILLING)

Few primary school teachers have the facilities to kill a small mammal, should this be necessary. Some would not wish to do so. The best solution is to take the mammal to a veterinary surgeon.

For those who have the facilities we recommend a method of euthanasia described by the scientific staff of the Universities Federation for Animal Welfare as 'outstandingly simple and humane': a plastic bag of appropriate size is slipped over the cage containing the mammal; one end of a flexible pipe is connected to a cylinder of carbon dioxide, and the other end is inserted through the neck of the bag; it is held there loosely so that air can escape from the bag as carbon dioxide is passed in; after 30 seconds, or when the mammal becomes motionless, the gas is turned off, the pipe is withdrawn, and the neck of the bag is tied off with string. After 10 minutes the mammal should be picked up to confirm that it is dead, and then disposed of, preferably by incineration. Those who have used this method confirm that the mammals simply become unconscious and die without any sign of agitation. Carbon dioxide, unlike chloroform and ether, is tasteless and odourless.

This method of euthanasia seems to have a very wide applicability being also suitable for birds, reptiles, and amphibia. Further details can be obtained from the Universities Federation for Animal Welfare, 7a Lamb's Conduit Passage, London WC1.

Cages and equipment

CAGE DESIGN

The main requirements of a cage are that it should retain the animal, be easy to clean, rot-proof, resistant to gnawing, and well ventilated but free from draughts. Size, as well as feeding and drinking arrangements, must be suitable for the species of mammal housed in the cage. General purpose cages suitable for several species are preferable for use in schools, since space is usually not available in classrooms for more than one or two cages.

CAGE SIZE

As might be expected, the size of cage required is determined by the size and activity of the animal. The height and width of a cage should not be less than the length of the fully grown adult mammal, excluding the tail, but this is a minimum requirement and larger dimensions are preferable. A cage with internal dimensions of approximately 18 x 12 x 9 in. is large enough for a fully grown rat, and for smaller mammals such as hamsters, gerbils, and lemmings. A fully grown guinea pig ought to be housed in a cage measuring at least 24 x 18 x 12 in., while a medium sized rabbit needs a cage about 36 x 24 x 18 in. Smaller sized cages than these may be adequate provided the mammal is taken out of the cage for regular exercise, but it is much better to give the mammal a spacious cage *and* have it out regularly for exercise. Cages to house a female and her litter should be larger than the sizes suggested.

Commercially made cages tend to reflect the needs of large mammal houses where space is at a premium. Thus a cage may be described as a rat cage although its volume is much smaller than our recommended minimum. The teacher should not be influenced by these economic considerations to the same extent but should put the animal's needs first. If there is no space in the classroom for an adequate cage, it is better not to keep mammals there at all. Larger cages are more expensive, but those of good design and construction will give many years' service. Some advice on choosing a cage is given in the next section.

Detailed instructions for making cages are found on pages 35-49. Further comments will be found in the sections on particular species, pages 50-76.

Choosing a cage

Apart from size, the chief factors to consider are these:

(*a*) The suitability of the material used in the construction of the cage, this usually being metal, plastic, or wood;

(*b*) The type of floor, usually either solid or wire mesh.

Painted metal cages are not very durable. Unfortunately, they are the type most commonly sold in pet shops. They cost about £1. A high quality all metal cage suitable for mammals up to rat size is unlikely to cost less than £5 (figure 2a). On the other hand, good quality cages made from plastic, with metal tops and of a similar size, can be purchased for about half the price of an equivalent all metal cage (figure 2b). We have tried a number of these cages in schools and have found them durable, easy to clean, and reasonably free from draughts. So far as we can tell, they are not affected by animal urine or very hot water and the usual detergents. The soft plastics become scratched easily, which indicates that they are not tough enough to withstand gnawing, but in no case has a cage been gnawed, because there are no exposed edges within reach of the mammals' teeth.

We recommend plastic box-type cages with solid floors as the most appropriate form of caging to use in schools for mammals up to the size of a rat. Apart from their suitability as caging the plastic box can be used for other purposes also.

Cages with a wire mesh floor have a tray beneath containing an absorbent material such as peat or sawdust to collect urine and faeces. If the mesh is of an appropriate size, most of the mammal's droppings fall into the tray where they are out of the animal's reach. This arrangement is convenient in so far as the tray can be emptied and cleaned while the animal remains in the cage, but the whole cage should be thoroughly cleaned and disinfected at regular intervals. Another problem is that the mammals sometimes get sore feet or hocks, particularly if they have not been used to mesh floored cages. Mesh floored cages are not suitable for breeding because the new-born young can get caught in the mesh. Some manufacturers offer a metal plate to be placed over part of the mesh during breeding. Since the larger mammals such as guinea pigs and rabbits produce greater quantities of urine and faeces than hamsters and other small mammals, the mesh floored cage is worth considering for them. Another factor to take into account is the ease of obtaining bedding (p. 22). If sawdust is available in quantity there is little point in having a mesh floored cage, because it takes only a few moments to change the sawdust every two or three days.

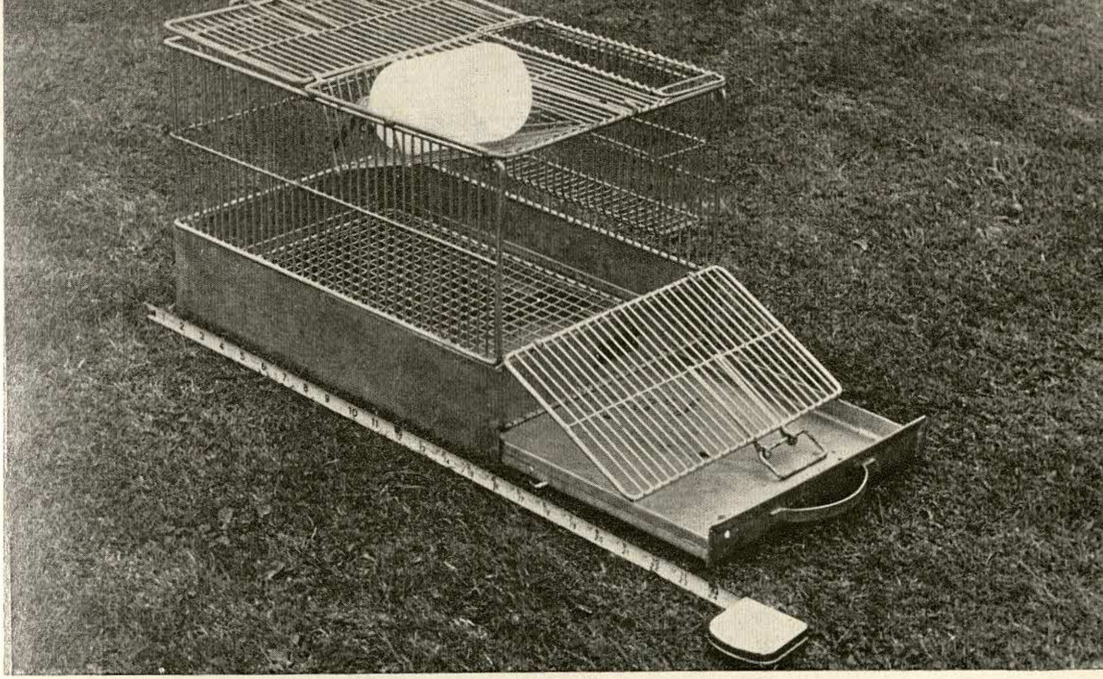


Fig. 2. (a). A commercially made galvanized cage with $\frac{3}{8}$-in. square mesh floor and drawer-type tray. Internal dimensions $15\frac{1}{2}$ x 10 x 9 in.

Fig. 2 (b). A commercially made plastic box cage with a translucent polypropylene box, raised mesh lid, and removable food hopper and water bottle. Internal dimensions $16\frac{1}{4}$ x 10 x 8 in.

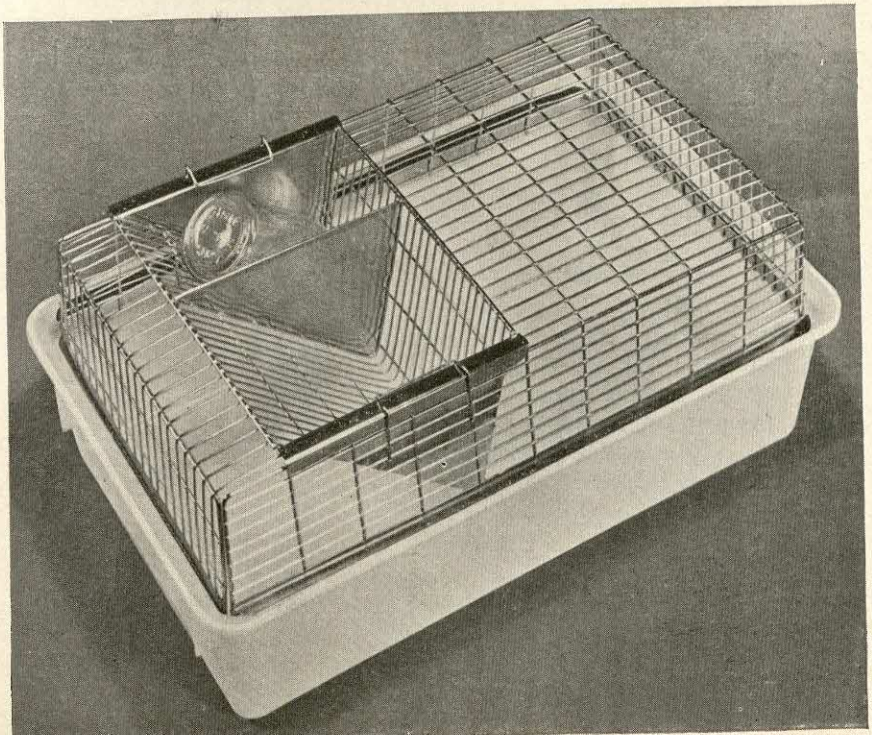


TABLE 2

A comparison of plastic box-type cages.

Ref.	Type of plastic	Size of box inside rim	Cost of box	Cost of flat lid	Total cost (1966 prices)
AC	Polypropylene	16½ × 10¼ × 6 in.	17s	18s	35s
NK	Polypropylene	16¼ × 10 × 4½ in.	18s 6d	18s	36s 6d
NK	Polycarbonate	16¼ × 10 × 4½ in.	31s 9d	18s	49s 9d
AC	Makrolon	16½ × 10¼ × 6 in.	60s	18s	78s

A comparison of raised mesh lids to fit polypropylene cages

Ref.	To fit box measuring	Final height of cage	Metal and finish	Weight of lid	Cost (1966 prices)	
					lid only	+ box
AC	16½ × 10¼ × 6 in	8 in.	Steel, hot dip galvanized	52 oz	21s 6d	3[illegible] 6d
NK	16¼ × 10 × 4½ in	8 in.	Steel, zinc plated	34 oz	34s 3d	5[illegible] 9d

A comparison of stainless steel lids to fit boxes measuring approx. 16 x 10 x 5 inches (inside the rim)

Ref.	Type of lid	Cost—lid only	Cost with polypropylene box	Cost with polycarbonate or Makrolon box
AC	Flat type lid	36s 6d	53s 6d	Makrolon 96s 6d
NK	Flat type lid	28s 3d	47s 3d	Polycarbonate 60s 6d
AC	Raised lid—cage height 8 in.	41s 6d	58s 6d	Makrolon 101s 6d
NK	Raised lid—cage height 8 in.	52s 3d	70s 9d	Polycarbonate 84s

Key AC—Associated Crates Ltd., Coronation Street, Stockport.
NK—North Kent Plastic Cages Ltd., Home Gardens, Dartford, Kent.

A comparison of manufactured cages

Many teachers have asked us for specific guidance on buying cages. Although we could not deal with every type available, table 2 on page 32 gives a comparison of some plastic cages of similar shape and size. They are suitable for small mammals up to rat size. Table 2 and the following notes will give teachers a good idea of the range of cages available. Data on cages for guinea pigs will be found on page 70; for rabbits, page 74.

There are two chief types of plastic used in small mammal cages:

1. *Polypropylene*—This is translucent, white, and moderately flexible. The surface is smooth, but not 'glass smooth'. We found that the white deposit formed from dried hamster urine was rather more difficult to remove from polypropylene than the other types of plastic. It is cheaper than the other plastics used in animal cages.

2. *Polycarbonate*—This is made in two grades:

(*a*) Makrolon—the trade name for a high quality grade which is transparent with a slightly bluish tinge. This is the strongest and most durable plastic used in animal cages and the only drawback is its high price. It is the only kind of plastic used in mammal cages which could be described as transparent.

(*b*) A cheaper grade which is semi-transparent with a yellowish tinge, and is generally referred to as polycarbonate. It appears to be intermediate in strength between polypropylene and Makrolon. It costs about half as much as Makrolon. Table 2 compares similar-sized cages made from these plastics.

The various types of cage top are described as stainless steel, galvanized, or zinc-plated. Stainless steel does not rust and is very strong. It is more expensive than the other types, but we have found wide variation in the cost of similar types of stainless steel top made by different firms. The teacher is advised to consult more than one catalogue before making a choice. Table 2 indicates something of this variation. The galvanized tops that we have examined are strongly made and the zinc coating is thicker and therefore perhaps more durable than a zinc-plated finish. However, the hot-dip method used to galvanize the tops produces an uneven coating of zinc, whereas the electrolytic method used for zinc-plating gives a thin but uniform coating. The immediate effect is on appearance, the zinc-plated tops looking much smarter than the galvanized variety. Obviously the thickness of wire and the design of the top will both affect its strength, but we are not able to estimate the 'life expectancy' of cages in a significant way since conditions of use vary so much. Some cage tops are flat. In this case the height of the cage is effectively the height of the plastic box. Others, called raised tops, add to the overall height of the cage.

The cages listed in table 2 are all of approximately the same floor area. Their heights differ and greatly affect the range of species that should be housed in them. Thus:

Height	*Suitable for*
4½ in.	mice, steppe lemmings
6 in.	mice, steppe lemmings, gerbils, hamsters
8 in.	mice, steppe lemmings, gerbils, hamsters, rats

The distance between the bars of the mesh top also affects the suitability of a cage for the smaller mammals. The recommended spacing for cages suitable for mice is ¼ in. Unfortunately, some manufacturers do not give details of the mesh in their catalogues. All the flat top lids listed in table 2 are suitable for mice. Of the raised top lids listed, the A.C. pattern cage is suitable for them. The N.K. type has bars spaced at ⅜ in.

Taking into account price, strength, and suitability for a wide range of small mammals, there seems little doubt that of the general purpose cages we have examined the A.C. polypropylene gives the best value. The box measures 16½ x 10¼ x 6 in. The raised mesh lid is 2 in. high, giving an overall height of 8 in. This cage costs £1 1s 6d. A cage of the same type measuring 20 x 12¼ x 6 in., plus 2 or 4 in. extra on the height depending on the lid, is also very good value for anyone wanting a somewhat larger cage. (See table 4, page 70.)

Those who can afford the more expensive plastics can choose between the N.K. polycarbonate cage, 16¼ x 10 x 8 in. at about £3 6s, and the A.C. Makrolon cage of about the same size at about £4 1s 6d. The N.K. cage is probably better value here, although it is impossible to say how much longer one might expect the Makrolon box to last. Transparency might be thought worth paying extra for, if, for instance, the box is also to be used as an aquarium, but the plastic becomes scratched sooner or later.

One advantage of the N.K. raised top cages over the A.C. types is that the food hopper and water bottle holder unit can be removed, leaving the main part of the top in place. The most recent model has a fixed hopper and a hinged door in the cage top. Both give easy access to the cage when one animal has to be removed from a group without the others escaping. Those who prefer not to use pellet diets can dispense with the food hopper entirely in order to leave more space inside the cage. In this case, a home-made top of Gridweld wire mesh is fitted over the opening and the water bottle is fixed to the side of the cage with curtain wire. This is fitted on the same principle as the one in figure 11b.

HOME-MADE CAGES

Since the high cost of commercial caging may be a deterrent, we include information about home-made cages. These are, of course, much cheaper since the cost is limited to the materials used and there are no additional labour costs and profit margin. A cage large enough for a rat and also suitable for smaller mammals can be made for about 15 shillings.

The teacher will have to decide whether he and his class can find time for making cages. Some would find much educational value in tackling the construction of cages, although perhaps few would go so far as one mixed class of eleven-year-olds which made twelve small mammal cages for £6 and eventually recovered this outlay by rearing, breeding, and selling hamsters.

It is not difficult to construct a cage which is far more versatile than any made commercially. The one illustrated in figure 3 serves the following purposes:

1. Small mammal cage for the rat, hamster, gerbil, lemming, mouse.
2. Vivarium: see chapter 3 (page 114) for details of modifications.
3. Locust cage: see chapter 5 (page 192).
4. Caterpillar cage.
5. Butterfly or moth emergence cage.

Fig. 3. A home-made general purpose cage.
Internal dimensions 18 x 11 x 8 in.

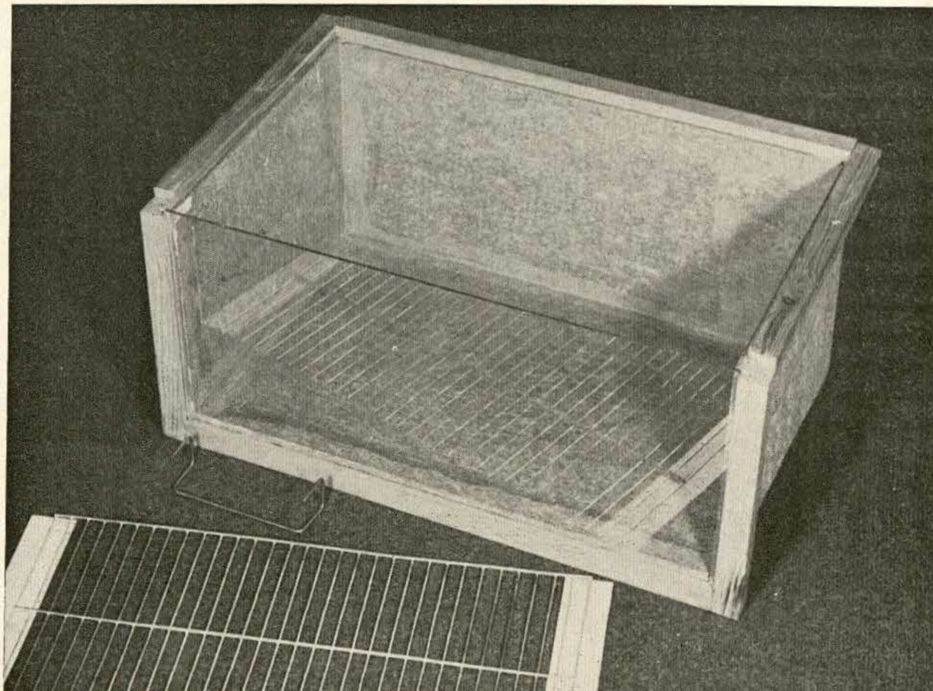


TABLE 3 A comparison of sheet materials used for cage construction

Name	Thickness	Price per square foot	Remarks
Concrete asbestos	3/16 in.	9d	Does not rot or rust. Water sinks in slowly, but it is practically waterproof. Rigid, can be shattered. Withstands gnawing.
Hardboard	3/16 in.	8½d	Does not rust but will rot in contact with water. Water sinks in rapidly. Pliable but strong. Exposed edges affected by gnawing.
Hardboard	¼ in.	9½d	As for 3/16 in. hardboard, but fairly rigid.
Oil-tempered hardboard	3/16 in.	11½d	As for 3/16 in. hardboard, but water sinks in slowly.
Oil-tempered hardboard	¼ in.	1s 1d	As for ¼ in. hardboard, but water sinks in slowly.
Birch plywood	¼ in.	1s 4d	Does not rust but will rot in contact with water. Fairly rigid and strong. Exposed edges affected by gnawing.
Birch plywood	3/8 in.	1s 11½d	As for 3/16 in. birch plywood, but more rigid.
Mahogany type plywood	¼ in.	1s 5d	As for 3/16 in. birch plywood, but better appearance.
Laconite	3/16 in.	2s 3d	Hardboard with a plastic facing. Similar to hardboard in properties, but waterproof on one side. Plastic facing eventually chips away at edges.
Warerite	1/16 in.	4s 9d	A plastic laminate which does not rot or rust. Waterproof. Pliable, can be shattered.
Formica	1/16 in.	5s 9d	As for Warerite.

Construction of a general purpose cage

The internal dimensions of the cage illustrated are 18 x 11 x 8 in. The constructional material we first used was sheet concrete asbestos, 3/16 in. thick. This has several advantages: it does not rot or rust; it is strong; mammals do not gnaw or scratch it; the natural finish is reasonably attractive; and it is one of the least expensive sheet materials, costing about 9d per square foot. We found it easy to work with. We cut sheets by a method of scoring and breaking described below, a technique which does not seem to require as much confidence as cutting glass. Our first cages were not varnished, and although they continue to give good service after three years of use, the wooden frameworks of the cages are stained with urine at the corners where it has gradually soaked into the wood. The asbestos in these cages has acquired a whitish deposit in the corners from hamster urine. This has not weakened the asbestos. More recently we have sealed the internal surfaces and all wooden parts of our cages with transparent polyurethane varnish. Urine no longer soaks into the wood and seems not to affect the varnish in any way. Cleaning of these sealed cages is very easy since the sealed asbestos is very smooth and waterproof. We recommend this treatment for all home-made cages made from absorbent materials which are to be used for mammals. The success of polyurethane as a sealing agent has caused us to try other sheet materials which we had formerly rejected on account of their high porosity. Table 3 on page 36 compares these and other sheet materials with concrete asbestos. We realize that some teachers prefer to work with sheet materials which can be readily sawn, and also that offcuts of the more expensive plastic laminate sheets can sometimes be obtained at reduced prices, two factors which can affect a decision about which material to use.

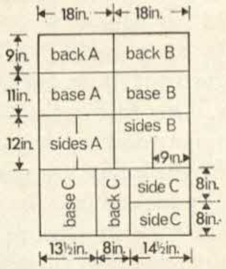
The following constructional details refer to a cage made from 3/16 in. concrete asbestos sheet. The dimensions quoted also apply to a cage made from any other sheet material of 3/16 in. thickness. If you use a material, such as Formica, which is less thick, the lengths of the wooden supporting pieces will be slightly different, as will the sizes of pieces of glass fitted to the front or top of the cage.

Instructions for making cages

The base, back, and sides of this cage are asbestos sheets screwed to $\frac{7}{8}$ x $\frac{7}{8}$ in. planed softwood. The front is a piece of 24 oz glass slotted into 3/16 in. grooves and the top is an 18 x 12 in. 'bird cage front'.

Fig. 4. Marking-out key and drilling key for home-made cage.

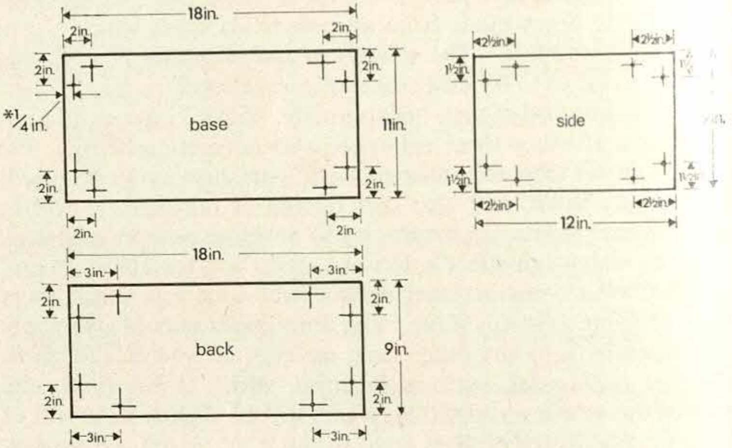
Standard size sheets of asbestos measure 6 ft × 4 ft and cost about 18s. This size is unwieldy. Ask the supplier to cut a sheet into two pieces each 3 ft × 4 ft



This marking-out diagram refers to a sheet of asbestos measuring 18 in. × 36 in. and is so arranged that there is no wastage of asbestos and the minimum of cutting. It produces two cages measuring 18 × 11 × 8 in. and one cage measuring 16 × 13½ × 7 in. (internal dimensions).

If only one cage is required, then the asbestos needed is a piece measuring 18 × 32 in.

Drilling diagrams



*Note: All the holes are drilled ¼ in. from the edge of the sheet material using a 5/32 in. drill

Mark out the asbestos and cut it to size. (Marking out diagram, figure 4.) One method of cutting asbestos is to score along the marked lines using the tang of an old file, or better still, a Stanley cutting knife fitted with a Formica scoring blade. Use a straightedge to guide the blade along the line. Run over the line several times using heavy pressure to produce a groove about 1/16 in. deep. Then line the groove up along the edge of the bench and break it by holding the sheet with one hand and pressing down the overhanging piece with the other. You must press down vigorously with one hand while holding on firmly with the other.

Trim up the edges with a large flat file. There is no need to go to great pains to get the pieces absolutely square, as it is usually possible to arrange for the best edges to be at the front of the cage.

Mark out the positions of the drill holes on the smooth surface of the asbestos, following the drilling diagrams in figure 4. The smooth surfaces are eventually fitted on the inside of the cage and it is a help to label the pieces 'back', 'side', etc., after cutting.

Centre-punch the drill marks and then drill the holes using a 5/32 in. metal drill which clears gauge 6 woodscrews.

Countersink the holes with a rose countersink bit. Some holes are countersunk on the smooth surface, others on the rough. Proceed as follows.

Base: All holes are countersunk on the smooth surface.

Back: All holes are countersunk on the smooth surface *except* the two holes on the base edge. These are countersunk on the rough surface.

Sides: The holes on the front and top edges are countersunk on the smooth surfaces, and the remainder on the rough.

Cut lengths of $\frac{7}{8}$ x $\frac{7}{8}$ in. planed deal to size according to the following cutting list for wood:

1 of 18 in.
2 of 9½ in.
2 of 8½ in.
2 of 18½ in.
2 of 9 in. grooved
2 of 11½ in. grooved

We found it more convenient to have the wood grooved at a timber yard. Most timber merchants have facilities for this, varying from circular saws (relatively crude but satisfactory) to spindlecutters (which produce a very clean cut). Charges vary from say 1d per foot, to 5s per 15 minutes' use of the machine (see figure 5).

Fig. 5. Cross-section of grooved wood pieces for front and top of home-made cage.

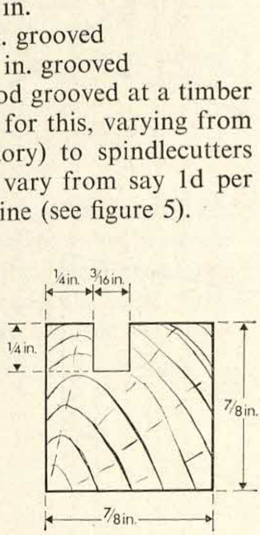
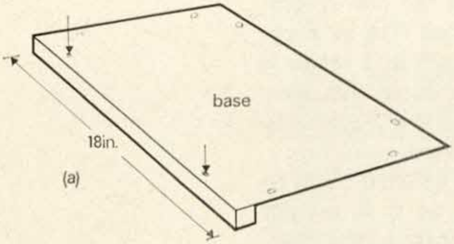
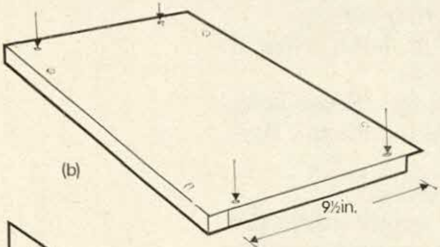


Fig. 6. Assembly diagrams for home-made cage.

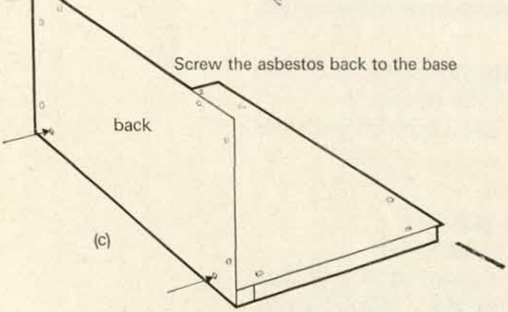
Screw an 18 in. length of wood to the base, flush with the rear edge of the asbestos, the smooth, surface of the asbestos being uppermost



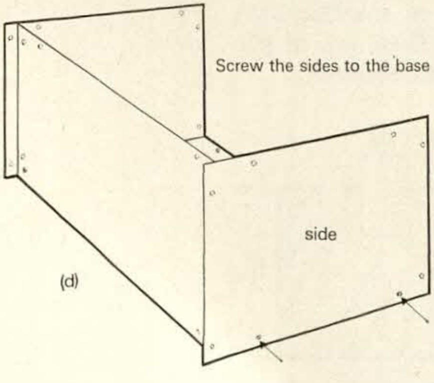
Screw two 9½ in. lengths of wood to the base, flush with the side edges



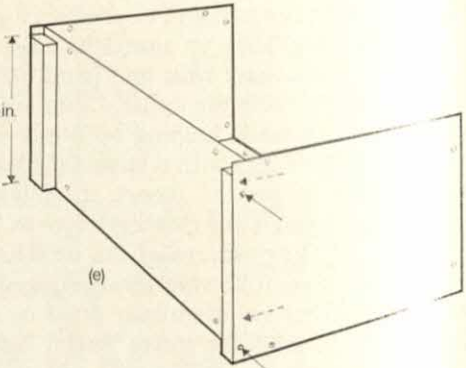
Screw the asbestos back to the base



Screw the sides to the base



Screw two 8½ in. lengths of wood to the sides and back, adjusting these so that they are square with the base



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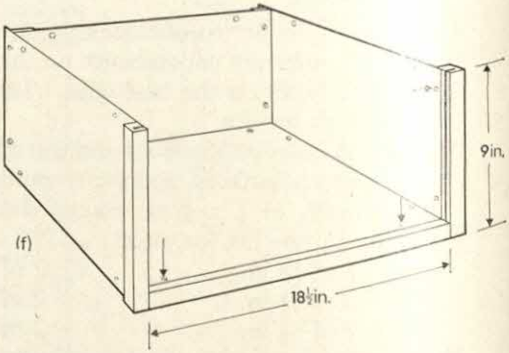

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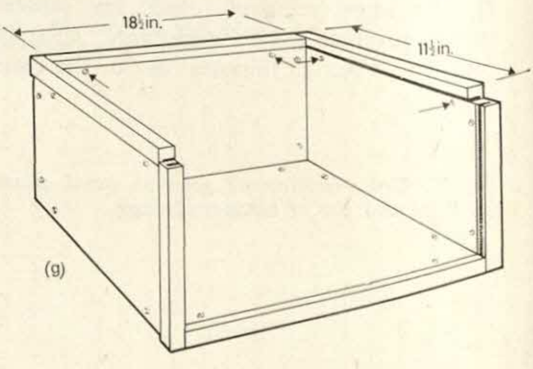


Assembly

The cage may now be assembled following the sequence described and illustrated in figures 6a, 6b, 6c, 6d, and 6e.

⅝ in. gauge 6 countersunk brass woodscrews are used throughout.

In copying figure 6f screw two vertical 9 in. lengths of grooved wood to the outer surface of the sides so that the grooves are just clear of the asbestos. Then screw an 18½ in. length of wood to the base, projecting beyond the front edge by ⅜ in. The ends of this piece of wood should be cut as shown in figure 7.

In copying figure 6g screw two horizontal 11½ in. lengths of grooved wood to the top edge of the sides so that the grooves are just clear of the asbestos. Then screw an 18½ in. length of wood to the back, projecting beyond the top edge by ⅜ in. This piece of wood should have its two ends cut as shown in figure 7.

The wire mesh top should be prepared as follows: Cut an 18 x 12 in. bird cage front to a size of 17½ x 12 in. With Evo-Stik glue pieces of offcut Formica measuring 12 x 1½ in. along each side of the mesh. Each piece should project by about ¾ in. so that the overall length of the mesh plus Formica is 18⅞ in. This size will slide into the grooves at the top of the cage.

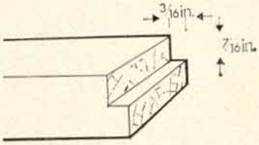


Fig. 7. Cutting the ends of the 18½-in. back pieces.

Glass front

For a glass front, use a piece of 24 oz. glass. Check the measurements across the front of the cage before having the glass cut to size, since there is a possibility that the asbestos is not quite square. Generally, a piece measuring 18⅞ x 8⅛ in. is the correct size. Smooth the edges of the glass on an oilstone. We found that the best way to do this was to lay the glass flat on the bench with one edge overhanging slightly. The oilstone, moistened with oil, is rubbed along the edge, while the glass is held firm with the other hand.

As an additional precaution, the top edge of glass may be bound with Sellotape or plastic adhesive tape.

Wire mesh front

Some teachers prefer not to use glass at all because of the danger of breakage. A wire mesh front can be fitted on the same principle as already described for the top, having overall dimensions of 18⅞ x 8⅛ in. A 2 in. wide strip of Formica glued across the base of the mesh front helps to prevent sawdust and other bedding materials from spilling out when the cage is in use.

Perspex instead of glass

Perspex sheet can be used for the front instead of glass. It is more expensive and eventually becomes scratched, but is quite satisfactory.

Finishing off

Gaps between the edges of asbestos inside the cage can be sealed with Polyfilla. Bostik sealing compound, cement, or putty might also be tried. Then the internal surfaces of asbestos and all wood surfaces should be given a coating of polyurethane varnish which is very durable, waterproof, and urine-resistant. We use clear matt finish, costing 6s 6d per half pint. This quantity is sufficient for several cages.

Locking device to prevent escapes

The more active small mammals such as hamsters and rats sometimes learn how to open the cage by sliding the mesh top. A simple locking device made from a 12 in. length of stout wire can be fitted to the rear of the cage. The device is shown in figure 3.

Construction of a guinea pig cage

A guinea pig cage can be constructed like the general purpose cage. The dimensions should be 24 x 18 x 12 in. The sides and back are asbestos sheets screwed to $\frac{7}{8}$ in. square wood strips. The front is a piece of Gridweld welded wire mesh which slides into grooved wood strips screwed to the sides of the cage. Addresses of suppliers can be obtained from the manufacturers, G.K.N. Engineering Ltd., Woodhouse Lane, Wigan, Lancs. The lower four inches of the mesh front are covered with asbestos. This acts as a splash-front, preventing sawdust from spilling out of the cage when the animals are living directly on the sawdust. In normal use, the cage stands on a mesh base also made from Gridweld. The mesh size is 3 x $\frac{1}{2}$ in. Beneath the mesh floor are two trays containing bedding. These can be made from such materials as metal, or plastic faced hardboard on a wooden frame or roofing felt.

The cage top is also made from Gridweld, but we have not found this essential since guinea pigs are poor climbers and jumpers. The water bottle is a 540 cm³ glass plasma bottle with a nickel-plated brass top with a long bent nozzle. A suitable type is supplied by

H. K. Bowman Ltd., and costs about 12s. If desired, a food hopper can be bought to fit on to the outside of the cage with the mouth of the hopper projecting through a square hole cut in the cage wall. One suitable type of hopper is made by Associated Crates Ltd., Stockport, price £1 6s 9d. Alternatively, galvanized cups can be fitted to the inside of the cage as described on page 46. These are much cheaper, costing about 5s each.

Construction of a rabbit cage

Details are given below for the construction of a rabbit breeding cage made from asbestos sheet. Any other sheet material may be substituted for the asbestos subject to the limitations of the material (see table 3). The general method of construction is exactly the same as for the general purpose cage described in greater detail on pp. 38-41. We recommend that this section be read before starting construction. The internal dimensions of the cage are 36 x 24 x 20 in. The base, back, and sides are asbestos sheets fixed with brass screws to the inside of a $\frac{7}{8}$ in. sq. wooden framework so that the rabbit cannot gnaw the wood. The top is of wire mesh, $\frac{1}{2}$ in. or 1 in. square holes being satisfactory. The front is a pair of hinged wooden doors with wire mesh fixed to the inside. If it is desired, the top could be made removable.

A sheet of asbestos measuring 6 x 4 ft will be needed, and there will be some wastage in the cutting. It is possible to make a cage measuring 48 x 23$\frac{1}{2}$ x 23 in. high from the same size of sheet with no wastage and the minimum number of cuts. A cutting diagram for this larger size is included in figure 9, should anyone wish to make it.

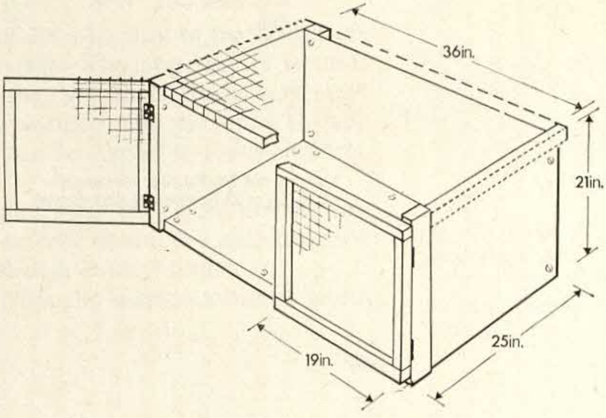
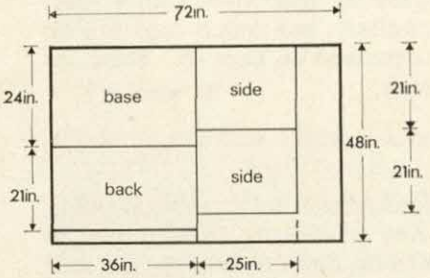


Fig. 8. Home-made rabbit cage with hinged doors and mesh top.

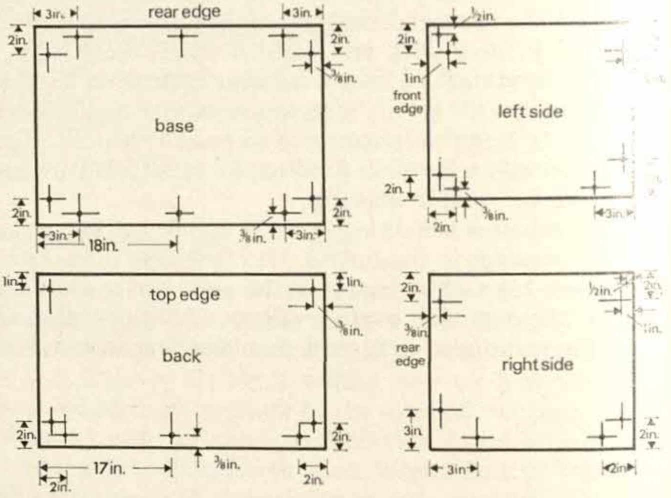
Fig. 9. Marking-out key and drilling key for home-made rabbit cage.

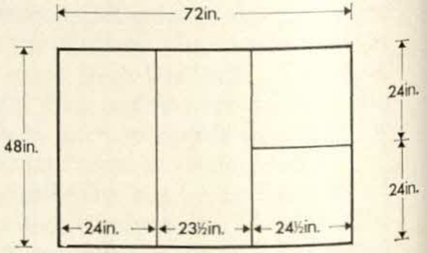


Marking-out key for cage measuring 36 × 24 × 20 in. (internal dimensions)

The overall size of the asbestos is 6 ft × 4 ft
Ask the supplier to cut it into two pieces each 3 ft × 4 ft

Drilling key
Mark out on the smooth surface of the asbestos





Marking-out key for cage measuring 48 × 23½ × 23 in. (internal dimensions)

Details of construction

1. Mark out the asbestos (figure 9).
2. Score the asbestos along the marked lines. You can saw the asbestos but it is generally quicker to score along the lines with a Stanley knife fitted with a Formica scoring blade. (Some people use the tang of an old file.) Draw the scoring tool firmly along the line a number of times to produce a groove approximately 1/16 in. deep.
3. Line up the groove along the edge of the bench and break the asbestos by pressing down firmly on both sides of the groove.
4. Trim up the asbestos with a large flat file.
5. Mark out the drill holes on the smooth surface of the asbestos. This smooth surface eventually forms the inner surfaces of the cage. (Drilling diagrams are in figure 9.)
6. Drill all holes with a 5/32 in. drill. (This size clears G.6 woodscrews.)
7. Countersink the holes as follows:

   Base: all holes countersunk on the smooth surface.

   Back: all holes countersunk on the smooth surface *except* the three along the base edge; these countersunk on the rough surface.

   Sides: all holes countersunk on the rough surface *except* the two along the front edge; these on the smooth.
8. Cut lengths of $\frac{7}{8}$ x $\frac{7}{8}$ in. deal to size. (See cutting list below.)
9. Assemble the cage as follows:

   Screw the 36 in. lengths flush with front and rear edges of base.

   Screw the $21\frac{1}{4}$ in. lengths flush with the side edges of the base.

   Screw the back onto the base.

   Screw the sides onto the base.

   Screw the two 21 in. lengths to the sides and back, adjusting so that these are square with the base. Then screw the 36 in. length to top front.

   Screw the two 21 in. lengths of 2 x 1 in. deal to the side pieces of asbestos at the front of the cage. The larger size of wood is used to give a firm support to the cage doors. If the wire mesh top is to be fixed, then screw wooden supports along the top outside edges. The mesh top can be stapled to these supports.
10. Make and fit the cage doors.
11. If the cage is not to have a wire mesh false floor and tray to catch the droppings it would be wise to seal the asbestos floor with varnish—polyurethane varnish is very durable.
12. A nesting box can be made from the surplus asbestos pieces (figure 10).

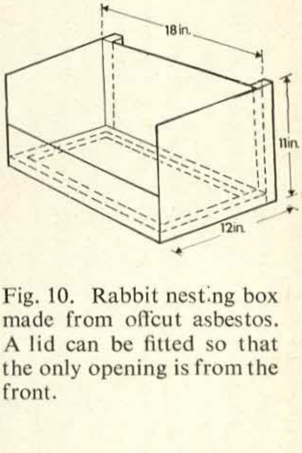


Fig. 10. Rabbit nesting box made from offcut asbestos. A lid can be fitted so that the only opening is from the front.

Cutting list for rabbit cage

(*a*)	Asbestos:	Base—36 x 24 in. Back—36 x 21 in. Sides—25 x 21 in.—2 pieces
(*b*)	Wood:	Base—⅞ x ⅞ x 36 in.—2 pieces ⅞ x ⅞ x 21¼ in.—2 pieces Back—⅞ x ⅞ x 21 in.—2 pieces Sides—2 x ⅞ x 21 in.—2 pieces Top front—⅞ x ⅞ x 36 in.—1 piece Top sides—⅞ x ⅞ x 24 in.—2 pieces Top back—⅞ x ⅞ x 34 in.—1 piece Doors—⅞ x ⅞ x 19 in.—4 pieces ⅞ x ⅞ x 19¼ in.—4 pieces
(*c*)	Wire mesh:	Top—38 x 28 in.—1 piece Doors—21 x 19 in.—2 pieces
(*d*)	Woodscrews:	Gauge 6 brass, countersunk, ¾ in. long—0
(*e*)	Hinges:	2 pairs, brass butts, 3 x ¾ in. and screws to fit
(*f*)	Staples:	Enough for fixing mesh to top and doors—½ in.

FOOD POTS AND WATER CONTAINERS

The simplest arrangement is to throw the food into the cage and have no receptacle for it at all. This results in no more wastage than when a shallow open food pot is used. The method is satisfactory for hamsters, lemmings, and gerbils. These produce only small amounts of urine and the bedding in their cages remains clean and dry for long periods. Young animals may become trapped under food pots.

Shallow food dishes can be placed on the floor of the cage. We have found 'shoes' for chair castors suitable for hamsters. They are heavy, easily cleaned, and cheap (about 6d each). Dishes with round internal corners are much easier to clean than rectangular pots. In the case of the hamster, the chief function of the pot is to familiarize the animal with a source of food. The hamster's habit is to transfer all the food provided to a 'store' in one corner of the cage. The empty dish should not be taken as a sign that the hamster has eaten all the food and needs a further supply.

Food pots which can be fixed to the side of the cage are useful since less food is spilt, but the pot must be easily removable for cleaning. We found a galvanized pot most useful for guinea pig food. It is illustrated in figure 11a. This could also be used for rats. The same type of dish makes a useful water pot for a guinea pig or rat. The pot can be fixed to the cage wall with a length of stout wire such as $\frac{1}{8}$ in. brass welding rod, or bicycle spoke. This is threaded through loops which project through the cage wall as illustrated. We do not advise the use of these pots in a solid floored guinea pig cage since the animal tends to kick up litter and faeces into the pot. Galvanized cups can be obtained from S. Young and Sons, Ltd., Misterton, Somerset. They cost 5s 6d each, or £1 7s 6d for half a dozen. Plastic food pots, $4\frac{1}{2}$ x $2\frac{1}{2}$ in., can now be bought in some pet shops. They are cheaper, costing about 2s 6d and worth a trial.

It is not very satisfactory to keep water in open-top containers: the water becomes fouled, and it tends to be spilt. All small mammals can be trained to drink from a water bottle fitted with a metal, glass, or plastic tube. This device ensures that water will stay clean. Training simply involves setting up the water bottle with the tip of the tube arranged at a height which the mammal can reach. Thereafter the animal should be watched to ensure that it finds the water supply.

Many types of water bottle are available. Wide-necked bottles are easier to clean than narrow-necked types. Glass is cheaper than plastic, but the latter is much more durable, polycarbonate and Makrolon especially so. Tops screw onto the bottle, and spouts may be straight or bent, short or long. The hole at the tip of the spout has a diameter of 2 mm. Commercially made spouts are of chromed brass, nickel-plated brass, Melamine (plastic) or stainless steel and nylon. We have used Melamine tops because they are much cheaper than the other types, and after one year there are no signs of wear. Bakelite tops are similar.

Home-made spouts can be constructed from hard glass tubing about 8 mm in diameter with fire-polished ends. The bore at the drinking end should be reduced to 2 mm in diameter.

To set up a water bottle in the home-made cage (figure 11b), a hole is drilled in the side of the cage for the spout. The bottle is secured to the cage with a short length of plastic covered curtain wire attached to a cup hook. It is easier to see the water level in a glass or clear plastic bottle than in one made of translucent Polythene. Mice, hamsters, gerbils, and lemmings drink only small amounts of water, and for them we think the best value water bottle is an 8 oz or 10 oz wide-necked transparent plastic (polycarbonate or Makrolon) bottle with a Melamine or Bakelite top. The top should have a long straight nozzle, about $1\frac{1}{2}$ in. in length. This costs from 3s 3d to 4s 1d, complete. For rats, guinea pigs, or rabbits, we recommend a larger wide-necked bottle such as the glass blood

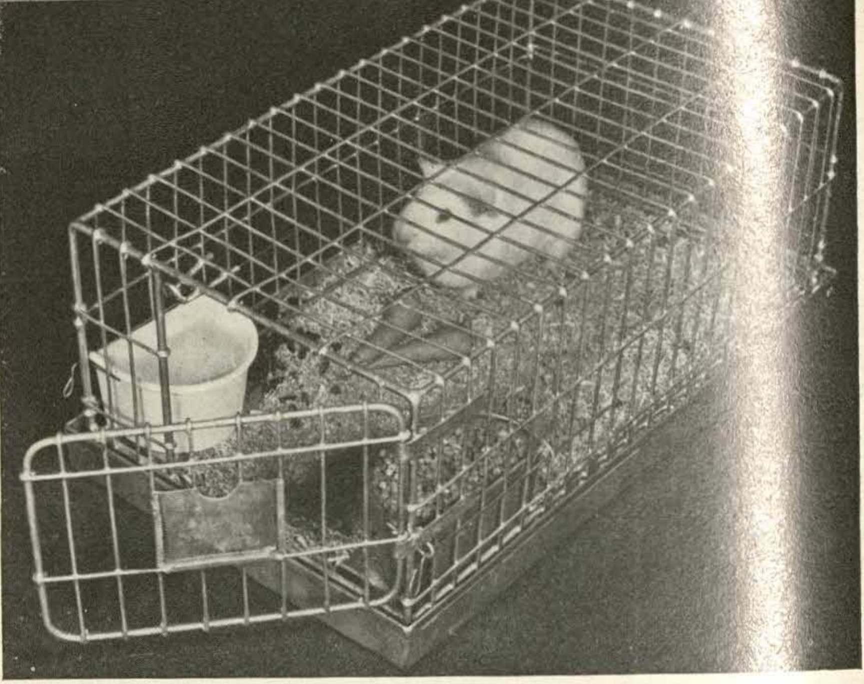
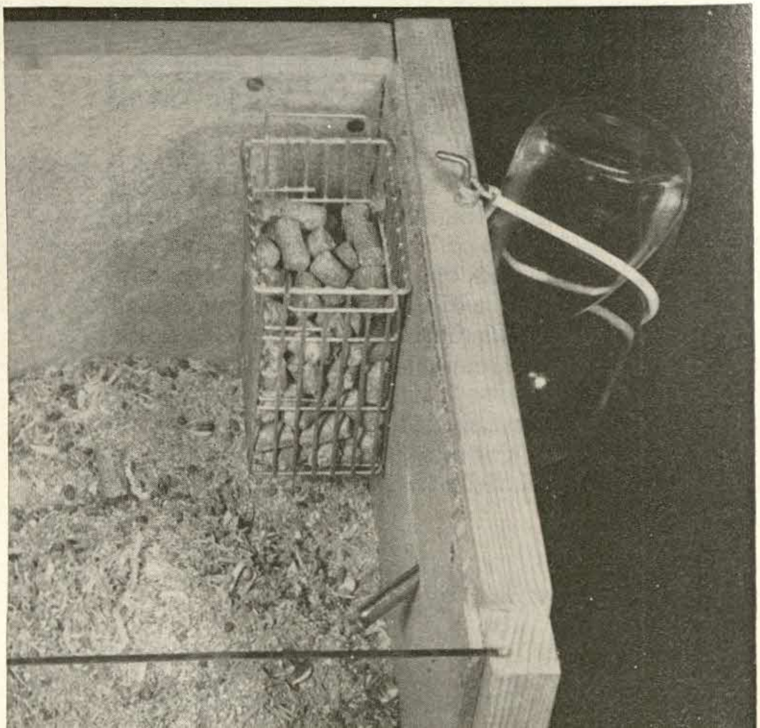


Fig. 11 (a). Galvanized and plastic food pots for a guinea pig cage. Loops projecting from the food pots through the mesh are threaded with a brass rod which holds the food pots fast.

Fig. 11 (b). A water bottle fitted to a home-made cage. The bottle is held fast by a short piece of curtain wire. Note also the detachable food hopper.



plasma bottle of about 500 cm^3 capacity, fitted with a nickel plated top or stainless steel and nylon top, in each case having a bent spout. Bottle plus nickel plated top costs about 12s and the stainless steel and nylon type 13s, complete.

HOPPERS

Many types of commercial cage include food hoppers. Mouse and rat cages generally have a wire mesh food hopper designed to contain composition food pellets of $\frac{5}{8}$ in. diameter. The hopper is kept at least half full and the mammal takes its requirements by gnawing at the pellets from beneath. If the hopper is nearly empty the animal sometimes has difficulty in feeding because the pellets move about. The advantage of a hopper is that several days' supply of food can be given and the food is not contaminated by contact with the mammal's urine or faeces. Some wire mesh food hoppers are detachable and sold separately. The one illustrated in figure 11b in use in the home-made asbestos cage costs 5s in zinc-plated steel or 7s 6d in stainless steel. It is supplied by North Kent Plastic Cages Ltd., Home Gardens, Dartford, Kent.

Hoppers with a solid base and open front are suitable for small pellet diets, powder feeds, or grain. A guinea pig hopper of this type (figure 12) needs to be at least 3 in. wide so that a fully grown animal can get its head into the hopper. Medium or large rabbits need an even wider hopper. Some firms do not quote the dimensions of the hopper and it is wise to check on this point before purchase. Hopper feeding arrangements for guinea pigs and rabbits are nearly all of this type since the standard pellets for these species are only 3/16 in. in diameter. (See section on food, page 21.)

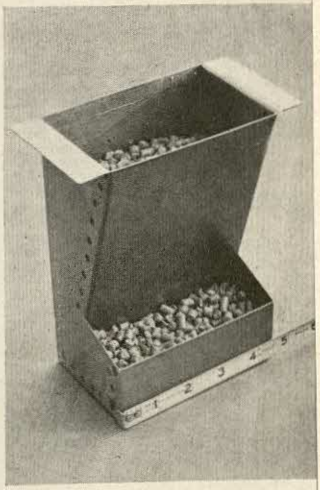
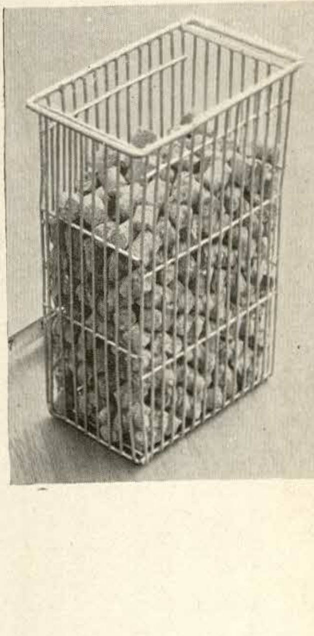


Fig. 12. Food hoppers: chute hopper (above) for small pellets used for rabbits and guinea pigs; wire mesh food hopper (below) for larger pellets used for rats, mice, gerbils, hamsters, and lemmings.



OUTDOOR CAGES

Guinea pigs and rabbits are hardy mammals and may be kept out of doors. A weather-proof hutch with an attached pen gives the animals more space and a place to seek shelter during bad weather, but the teacher must be certain that the animals will not suffer from interference by hooligans or stray animals. Guinea pigs cannot jump and may be kept in open top pens, 18 in. high, but these must not be left unattended if dogs have access to the area. Fuller information will be found in the sections dealing with guinea pigs (page 67) and rabbits (page 72).

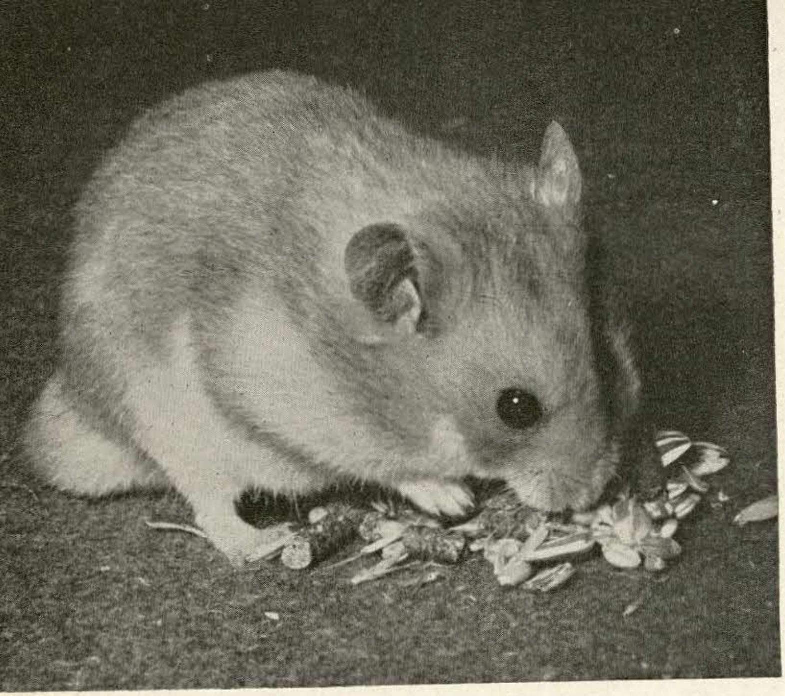


Fig. 13. Adult male golden hamster.

Notes on selected species

THE GOLDEN HAMSTER (*Mesocricetus auratus*)

Origin

Three species of hamster have been kept in captivity. Of these, only one, the golden hamster, *Mesocricetus auratus* (figure 13), is really suitable for school use. Anyone interested in the other two species should refer to Worden and Lane-Petter, *The U.F.A.W. Handbook on the Care and Management of Laboratory Animals*, 3rd edition.

The first record of the golden hamster is contained in the *Annals of Natural History*, 1840, which refers to a meeting of the Zoological Society of London held in 1839 at which Mr G. R. Waterhouse exhibited the new species, obtained from Aleppo in Syria. Some ninety years later, I. Aharoni, on an expedition to Syria, captured a litter of golden hamsters in a burrow near Aleppo, and brought back eight to the Hebrew University, Jerusalem. Of these, four escaped, one female was killed by a male, and only three animals—one male and two females—remained. According to Adler (1948), all the golden hamsters in use in European and American laboratories originate from these three litter mates.

It is virtually impossible to estimate the number of golden hamsters which have descended from this original litter. There are probably hundreds of thousands in various parts of the world, and the total produced since 1930 could well run into millions. There are more than a dozen varieties in existence, all selectively bred from this original stock. There are cream, albino, banded, and even tortoiseshell types. For school use we recommend the commonest type, the golden hamster, since it is a very attractive animal and the cheapest variety.

Habits of hamsters in the wild and in captivity

Like many desert-living small mammals, the hamster is a burrowing animal. It spends the greater part of its life underground where the extremes of heat and cold characteristic of the desert climate are largely avoided. Very few observations have been made of the golden hamster in its natural environment. Its diet probably includes seeds, roots, and other parts of plants, and possibly small invertebrates. Hamsters produce dry, spindle-shaped faeces and small amounts of urine. These features are characteristic of small desert mammals: they result in very little water loss. Hamsters drink very little in captivity and the same is probably true of the animal in the wild. In the desert, scarcity of water is a greater hazard than high temperature. Heat can be avoided by life underground. Water shortage tends to be linked with food shortage since plant growth is severely restricted under drought conditions. Hamsters appear to be well adapted to survive these conditions since they can manage on a surprisingly small food and water intake. Hindle (1957) and Magalhaes report that the average daily food intake of adult hamsters fed on pellets without supplements was 3 g at an environmental temperature of 22°C. Food intake is apparently greater at lower temperatures. The hamster has large cheek pouches in which to store food for short periods. In captivity, quantities of food are stuffed into the pouches and then disgorged close to the nest. This habit is best seen when food is given in open pots, since the animal cannot easily gather food from overhead hoppers.

If left to its own devices the hamster spends most of the day asleep, emerging at irregular intervals, with much yawning and stretching, to urinate in the chosen corner and then return sleepily to its nest. In the evening the hamster becomes very lively. It runs round the cage and climbs over the bars. This activity continues at intervals throughout the night and into the early morning. Hamsters mate in the evening too. This is a good reason to encourage children to take the animal home at weekends where they will get a much better picture of the hamster's behaviour. Some teachers say that nocturnal living habits make the hamster uninteresting for schools. Others argue that this is a useful feature since the animal is not a continuous distraction. In any case the hamster does not appear to suffer from being awakened. It can adapt to the lively atmosphere of the classroom, alternating bouts of activity with slumber. If food is placed in the cage during the day the hamster rapidly learns to come out and take it.

Management in captivity

Handling—Like most small mammals, the hamster becomes tame through frequent handling. The 'scoop' method (figure 1) is best, particularly for children, who have small hands. A nervous animal should be picked up with its head facing the handler so that it can only jump towards the handler, who will probably be able to catch the animal against his chest. Anyone who has never handled small mammals should have a demonstration from someone with greater experience since this is the quickest way to develop confidence. If a tame adult animal is not available it is wise to obtain a young specimen which will be more adaptable. A mother and young should not be handled until the young are at least 10 days old. The hamster's territorial instinct is strongest in the vicinity of the nest. It is sensible not to irritate a sleeping hamster by hauling it unceremoniously out of bed. Gentle coaxing, perhaps with the offer of a choice sunflower seed, is the best method of awakening the hamster.

Compatibility—Adult hamsters are usually housed singly and only brought together for breeding purposes. Even then they must be kept under close supervision, since stranger adults of the same or opposite sex always fight viciously. Groups of the same sex can be reared together indefinitely provided they are introduced to the stock cage all together, soon after weaning. Similarly, male and female pairs can be set up for life when aged 3-6 weeks old (see page 18).

Cages—A cage measuring about 18 x 12 x 6-9 in. is large enough for a pair of adults or a female and litter. Solid floored cages are preferable since the hamster produces relatively small amounts of urine and dry faeces. During the evening and early morning, hamsters are very active, particularly in a roomy cage. If the cage is designed to allow the animals to reach the overhead mesh they will exploit a much greater part of the cage volume by swinging from the bars hand over hand, or walking upside down. Another normal characteristic is a compulsive gnawing of parts of the cage, particularly those parts on which the animal's teeth can take hold. Home made cages should have no wooden parts accessible to the hamster. One must provide the animal with something to chew such as a small piece of wood. The large chisel-shaped incisor teeth, like those of other rodents, grow throughout life. Habitual gnawing of hard objects prevents the teeth from becoming overlong and possibly keeps them sharp.

Bedding and nesting materials—Sawdust or Sterolit are satisfactory bedding (see pages 22-3). Vermiculite is not recommended for hamsters since the animals seem to have difficulty in dislodging it from the cheek pouches where it may cause inflammation. The best nesting materials are clean paper wool, wood wool, cotton wool, or soft dry grass. Coarse hay or straw should not be used because sharply pointed pieces might pierce the cheek pouches.

Cleaning—The instructions for cage cleaning given on pages 23-25 are applicable here. Hamsters urinate in one part of the cage. The animal may learn to use a shallow tray placed in that corner. A tray about six inches square fits right into the corner and is large enough not to be easily overturned. It is a good idea to scrape up a little urine-soaked bedding and transfer this to the corner of the tray. When sawdust is used for bedding, weekly cleaning is advisable. A white, alkaline deposit accumulates in the urination corner. This should be scraped away when the cage is cleaned.

Food and water—A standard rodent pellet diet such as Diet 41B (see page 21) is suitable. It can be dispensed either in overhead food hoppers or in open dishes. Since hamsters store food, the empty dish is not a sign that more food is required. A tablespoon of dry food (about 20 g) for each adult, daily, allows a margin of storage. A mixed grain diet including wheat, sunflower seeds, maize, and porridge oats is also suitable. Whole oats should not be given since the sharp husks may pierce the cheek pouches and cause inflammation. Either type of diet should be supplemented with small amounts of fresh greens, root vegetables, or fruit. Surplus fresh food of this kind should be removed before it decays. Pregnant hamsters and females with litters should be given small amounts of milk daily. A tablespoonful is ample. Except for the female with litter, hamsters drink very little water, but a constant supply of clean water must always be available. A water bottle is the most convenient method of giving water (see pages 46-9). Water pots are sometimes overturned, possibly leaving the animal without water while the bedding is soaked.

Breeding—Hamsters can be sexed by comparing the distances between the anus and genital openings. In the adult male the distance is from ½ to ¾ in., whereas in the female it is about ¼ in. The testes protrude backwards (figure 13) and give the rump a tapered appearance, while the female's rump is rounded.

The female hamster becomes mature at an early age—six weeks. Some breeders prefer to wait until the females are two or three months old before they attempt a mating. The female's reproductive life lasts until she is between a year and 18 months old. The months February to October are the best times for mating, although hamsters will reproduce all the year round if kept warm. The female comes on heat once every four days. She mates with the male over a period of a few hours, usually in the evening, once during each four-day cycle. If the male is a stranger she will probably fight him at all other times. The gestation period is only 16 days. The litter size ranges from 4 to 9.

Two methods of breeding are commonly practised. One is to introduce a mature female into the male's cage on four successive evenings at any time from about 8 p.m. onwards. If the female fights the male she must be removed immediately, before she can do damage. When the female is receptive to the male she adopts a mating posture, with rump raised and body rigid. When this happens the male will mate repeatedly. The female should be removed after about 20 minutes.

The other method is to place a pair of hamsters together when they are weaned, and leave them together indefinitely. Under these conditions the hamsters grow up together in reasonable amity and mate at regular intervals once they are mature. Under this system the male remains in the female's cage throughout pregnancy, birth, and suckling of the young. The disadvantage of the system is that the female may be disturbed by the male and eat the litter, particularly if it is her first. Also, the time of mating and hence the expected time of birth are not predictable with any certainty, whereas with the method of trial mating these matters can be arranged.

While a hamster has young she should be disturbed as little as possible. The cage should not be opened during the first week after the birth of the litter, except to introduce a little milk. Cage cleaning can be deferred until the young animals are weaned at 21 days. The young should have access to the water bottle as soon as they start to leave the nest. Care should be taken to ensure that it is within their reach. Alternatively, they will drink some of the milk provided for the mother. The female should be given plenty of nesting material before she has her litter so that she can construct an adequate nest. The hamster, like many other small mammals, can build a nest which will enable her to control the conditions in the cage. Given appropriate materials, she will provide the best possible environment for her young.

Sources

Hamsters are included in the accreditation scheme run by the Medical Research Council's Laboratory Animals Centre (see page 15). Good quality stock can be purchased from any accredited breeder.

THE MONGOLIAN GERBIL (*Meriones unguiculatus*)

Origin

The Mongolian gerbil is a native of north-east China and eastern Mongolia. Related species are found in Asia, India, the Middle East and Africa. It has recently become established as a laboratory animal in the United States. Several colonies are now being maintained in Britain.

The advantages of keeping gerbils in schools were explored by the Elementary Science Study in America.* School trials in Britain have confirmed the American view that the gerbil is an ideal classroom and laboratory animal. Since it is unfamiliar to most teachers we include a short description of the appearance of the Mongolian gerbil.

Appearance and habits

This gerbil is an attractive, alert rodent with sandy brown fur on

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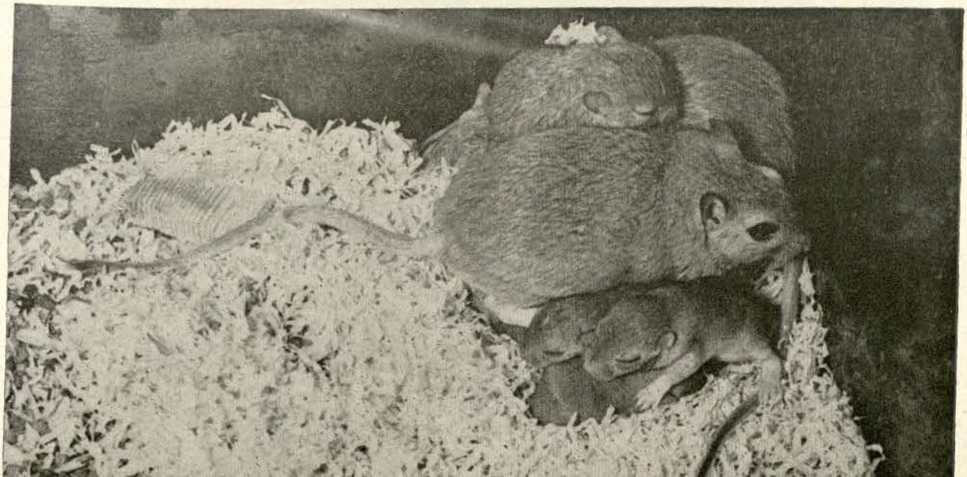
* We are grateful to Professor David Hawkins of E.S.S. who first drew our attention to this work.

Fig. 14. Gerbil with litter.



the back intermingled with some black hairs. It has white underparts, prominent black eyes, and well-pricked, slightly furry ears. The tail is furred with a black tip, and is slightly longer than the body. The adult gerbil is 4 or 5 in. long, excluding the tail. Mature males weigh 100-135 g and females from 70-90 g.

The animals appear to be moderately diurnal in habit, but are most active at dawn and dusk. In nature, they feed off roots and seeds. They apparently live in fairly large communities in subterranean burrows. The Mongolian gerbil is adapted to a desert environment; it shows considerable resistance to heat stress and dehydration. Some reports suggest that, like the hamster, it stores food in burrows and can hibernate.

Management in captivity

Handling—Mongolian gerbils are extremely tame. They are easy to handle, and almost never bite. They can be picked up by the 'scoop' method (figure 1). They show considerable curiosity and eagerly explore any new object such as a hand which is placed in their cage. Their curiosity has been a confusing factor in psychological research into animals' motives, where it seemed to be as important a drive as hunger. It is perfectly safe to handle pregnant females, breeding pairs with suckling young, or even the new-born young themselves—*provided* the handling is done in moderation. Recently weaned juvenile gerbils are rather agile and, in the classroom, should only be handled over the cage in case they are dropped.

Compatibility—Stranger adults will almost certainly fight when brought together. Single sex groups or breeding pairs can be reared together in the same cage provided they are introduced when young, preferably soon after weaning.

Cages—Gerbils thrive in any standard laboratory cage suitable for rats or golden hamsters. Solid floored plastic box-type cages are particularly convenient. A cage measuring approximately 18 x 12 x 9 in. is large enough for a breeding pair with young. Aquariums fitted with wire mesh lids have been used successfully. For short periods, Polythene washing-up bowls covered with wire netting will do.

Bedding and nesting materials—Sawdust, wood shavings, Sterolit, or clean dry sand are satisfactory for bedding. Nesting material in the form of wood wool, paper wool, cotton wool or paper towelling should also be supplied.

Cleaning—Mongolian gerbils and their cages are virtually odourless. The animals produce one or two drops of highly concentrated urine each day and their faeces are completely dry. Cages need only be cleaned once a week, and completely sterilized once a month. It is quite permissible to clean at less frequent intervals. Standard cleaning procedure as outlined on pages 23-25 should be followed.

Food and water—It is most convenient to feed the standard laboratory animal pelleted food Diet 41B or any standard rodent breeding diet. Grain mixtures are also suitable. The diet can be supplemented with very small amounts of fresh vegetables such as carrots, lettuce, cabbage, or other green vegetables. Being a desert mammal the Mongolian gerbil will not consume large amounts of green food. If food is given in open feeding bowls these should be fixed to the side of the cage or secured to its floor. They should not be placed on the bedding because gerbils usually excavate under the feeding bowl and may become trapped.

Water is most conveniently given in a water bottle fixed to the cage. If fresh greens are given daily it is possible to dispense with the bottle, but most teachers have found it useful during weekends. Provided there is an ample supply of food and water, the animals can be left unattended for several days.

Breeding—The sexes are easily distinguished. The testes are prominent in the adult male, altering the shape of the rump. The distance between anal and genital openings is greater in the male than in the female.

Gerbils become mature at 9-12 weeks and are best used for breeding after they are about three months old. Their reproductive life may continue until the animals are 18-20 months old, but sometimes ends much sooner. The oestrous cycle has not yet been precisely defined, but the female's cycle appears to be 4-7 days in length. The female allows the male to mate when she is on heat. This generally happens in the late afternoon or early evening. The male pursues the female in great excitement. He characteristically thumps his hind feet on the floor when excited. The female permits the male to copulate many times. The gestation period is about 25 days and the litter size is usually 4-6. The young are born naked and blind. Hair starts to develop at about 5 days and the eyes open at 16-20 days. At first the babies are entirely dependent on the mother's milk, but they start to nibble solid food after about the 16th day.

The simplest breeding system is to place male and female together before puberty—at less than 6 weeks of age—and house them together for life. Once they settle down together the male can be left with the female throughout pregnancy, birth, and suckling. The male is likely to mate with the female shortly after she has given birth to young. Under these circumstances pregnancy is extended, so that the female usually produces a litter every 30-40 days.

Sources

The Laboratory Animals Centre will supply details of reliable sources of Mongolian gerbils (see page 15). There are at present relatively few sources. Several Teachers' Centres have established breeding colonies. Specimens sold by commercial breeders cost about £1 5s each.

NOTES ON OTHER SPECIES OF GERBIL

Meriones libycus

This species is larger than the Mongolian gerbil, the male being somewhere between the golden hamster and the rat in size; adult females weigh about 120 grams and males 180 grams, compared with the Mongolian gerbil's 80-120 grams. It is of similar appearance, having light brown fur with black tips and a white belly. The eyes are large and black, the ears prominent and somewhat pointed, and there is a tuft of hair on the ridge of the tail. The species was first introduced into British laboratories in 1951 and breeding colonies have been established in several parts of the country. Management is similar to that of the Mongolian gerbil. For a summary of breeding characteristics see table 1 (page 26). Figure 4 (page 55) shows a female with a litter.

Meriones libycus is, if anything, easier to handle than *M. unguiculatus*, being of larger size and slower moving. It is very friendly and inquisitive and a healthy specimen reared in captivity does not bite under normal conditions. It seems to be an ideal classroom mammal, although it does not breed quite so readily in captivity as the Mongolian gerbil.

Meriones shawii

This is a most attractive looking gerbil, about the same size as *M. unguiculatus*, with a slightly more slender appearance. It has a pale sandy coloured back without black hairs. It is white beneath with white patches extending up to the muzzle and around the eyes. The eyes are prominent and black. The nose is rather pointed. The ears have very little hair. The tail is pink with a fine covering of white hair.

M. shawii is fast-moving and therefore more difficult to handle than the other species described. Its behaviour and breeding characteristics are broadly similar to those of the Mongolian gerbil. Management is the same as for the other species.

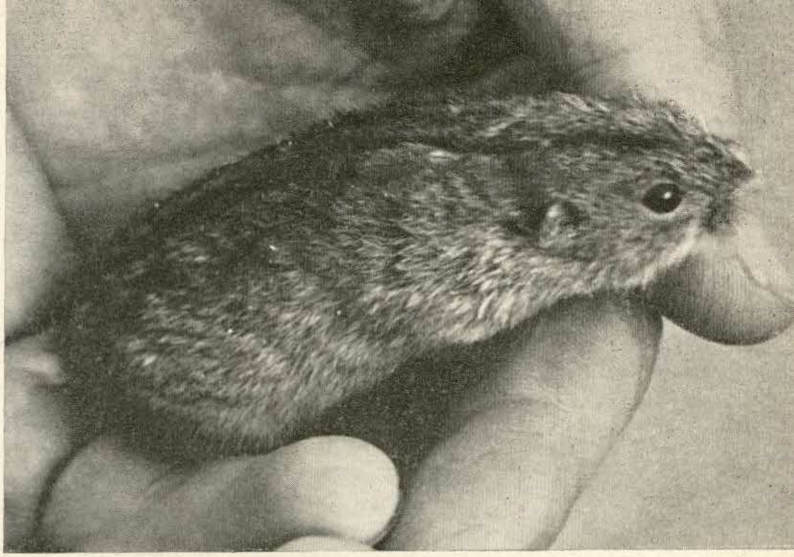


Fig. 18. Steppe lemming.

THE STEPPE LEMMING (*Lagurus lagurus*)

Origin

This is an interesting little animal which has recently become available in Britain and is very suitable for classrooms. There is relatively little published information about steppe lemmings and we are grateful for permission to quote extensively from the paper by Beckett, Fox, and Scribbans, 'The care and maintenance of the steppe lemming (*Lagurus lagurus*)'.

The steppe lemming is native in the arid zone of central Asia, in the north-western parts of North America, and in Russia, where it is found in a large area west of the Poltava district, by the Aral Sea, in the Stavropolian Steppes of the Altai, and in the Barkul mountains of the Dzungaria. It prefers clay steppes and semi-deserts but can also be found in districts of forest steppes, field ridges, pastures, and cornfields. It should not be confused with the much larger Norwegian lemming which is about the same size as a rat and is well known for its migratory habits.

The steppe lemming was unknown in British laboratories and zoos until 1958, when the Laboratory Animals Centre was presented with two pairs. One pair had a litter, but they failed to rear the young. After a few months, all four were dead. Then, in 1961, a further two pairs were brought back to the Laboratory Animals Centre. These bred successfully, so much so, that many laboratories and schools in this country, and abroad, have been supplied with stock.

Appearance and habits

The steppe lemming (figure 15) is about the size of a field vole. It has a soft furry coat in varying shades of grey, with a characteristic black stripe along the centre of the back. It has a very short furry tail, and short rounded ears which disappear into the fur. It has no smell. Steppe lemmings are active and inquisitive creatures, being neither nocturnal nor diurnal but polyphasic. They have 2-3 hours' activity and 2-3 hours' sleep all through the day and night.

Management in captivity

Handling—Steppe lemmings are quick moving animals and do not remain still in the hand. They can either be picked up with the thumb on one side of their bodies and the fingers on the other, or scooped up in the palms of the hands, as for hamsters. They seldom bite but sometimes peck. When on the hand this animal does not cling as a mouse does. If they fall they fall flat and awkwardly as one would expect of burrowing animals. For this reason steppe lemmings should be handled over a table.

Compatibility—Breeding pairs live together very successfully, but trios are unsuccessful as the females fight and seldom breed.

Cages—Plastic box cages with solid bottoms are very suitable, although any standard rodent cage suitable for hamsters or rats will be adequate. Circular glass troughs, 9 in. in diameter and 5 in. high, have also been used with success. Cages should be well ventilated to avoid condensation and possible respiratory troubles.

Bedding and nesting materials—Sawdust is a satisfactory bedding, and the best nesting material is dry hay, some of which is eaten.

Cleaning—Steppe lemmings produce very little urine and the faeces are dry. Standard cleaning procedure (see pages 23-25) should be followed once a week or a fortnight, but cages can be left for longer periods.

Food and water—A mixed grain diet including wheat, maize, sunflower seed, oats, and birdseed is suitable. This should be supplemented with small amounts of fresh vegetable, such as raw carrot or beetroot. Vegetables should be removed daily. Alternatively, a standard rodent diet such as Diet 41B can be given. Water should be available in a water bottle, but the animals drink very little.

Breeding—The sexes are distinguished in the new-born by the larger genital papilla and the greater distance between the anus and the genital papilla in the male. Once the animals have their fur they will be difficult to sex until they are much more mature. The best way to hold the animal for sexing is to scoop it up in both hands and then roll it over with the rear part of the body sticking out from between the hands, ventral side uppermost. Steppe lemmings reach maturity at about 28 days but if mated immediately they often lose their first litter. It is advisable to delay mating until the animals are 42 days old. A suitable maximum breeding age is 12 months. The oestrous cycle of the female is 4-5 days and the gestation period 19-20 days. The average litter size is 4 and the young should be weaned at 21 days, if they are not less than 7 grams in weight, and if another litter has not been born in the meantime. If there are two litters left in the cage there is a tendency to cannibalism.

The usual breeding system is to keep the animals together in pairs throughout their breeding life. The female comes on heat shortly after the birth of the young and mating usually occurs at this time. The males are good fathers and will protect the litter. Apart from feeding them, males try to rear the young ones if the female dies. Steppe lemmings live for about 18-20 months.

THE MOUSE (*Mus musculus domesticus*)

Origin

The laboratory mouse (figure 16) is bred in enormous numbers: over a million a year in Britain alone. It is descended from the house mouse. The origin of this animal is uncertain. Perhaps it arrived in Britain with the early agriculturalists. House mice are now found all over the world. The various sub-species are believed to descend from a form found in Russian Turkestan.

Habits

The wild house mouse is habitually found in association with man, living in his dwelling houses, factories, and warehouses, as well as in farms, barns, and haystacks. A part of the population lives at large in the fields away from direct association with man. The house mouse is a gregarious species which prefers warm, dark places although it is a most adaptable animal. As L. Harrison Matthews records:

'The most unexpected environment in which house-mice flourish is that provided by the cold stores in which meat is kept for long periods. Here the mice do well in what would appear to be very adverse conditions. In total darkness, and in a temperature never above 9·5°C, with no food other than meat, the mice breed and live their whole lives. They make their nests of the hessian material in which meat is wrapped, or of the fur and feather from stored

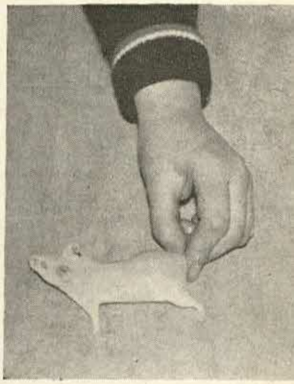


Fig. 16. Picking up a mouse by the base of the tail.

carcasses. Often they eat out burrows in carcasses of frozen meat and make their nests inside. Not only do the mice withstand the severe conditions, but they flourish on them to an unusual extent, so that the average size and weight of cold-store mice is above that of outside mice. Further, their reproductive rate is higher; they produce an average of a little over $6\frac{1}{2}$ litters a year compared with the $5\frac{1}{2}$ of domestic mice; the average number of young in each litter is also greater, being over $6\frac{1}{3}$ against a fraction above $5\frac{1}{2}$.

The laboratory bred and reared mouse is a more docile creature than its wild counterpart and is readily tamed. Mice breed very quickly and are much used in genetical work. Litters of a dozen or more young are not uncommon and sexual maturity is reached at 2 or 3 months, sometimes as early as 6 weeks. Laboratory mice are clean animals but the males produce a secretion containing acetamide, used for marking out territories, which gives mouse colonies a characteristic odour that some people find objectionable. In addition, mice urinate indiscriminately on the floor of their cage. This may add an ammoniacal element to the general smell especially if the standards of hygiene are not of the highest order.

Mice are indispensable laboratory mammals and are very useful in schools, particularly where breeding experiments involving coat colour are being performed. As pets, they have no outstanding features in comparison with other rodents. Teachers with sensitive noses may well choose some other classroom mammal.

Management in captivity

Handling—Of the small mammals kept in captivity, the mouse is the only one which may be picked up by its tail without harm (figure 16). The tail should be gripped near its base between finger and thumb and the animal transferred to the free hand or arm while the holder still retains a gentle hold on the tail. Alternatively the mouse may be picked up by the 'scoop' method (see figure 1).

Compatibility—Single sex groups may be reared in the same cage provided they are first placed together when young, shortly after weaning, but the males, especially, may fight when they reach sexual maturity and it is difficult to keep more than four males to a cage. Stranger adult males will probably fight one another. Breeding pairs, established when young, may be left together for life, provided one can cope with the large numbers of offspring. Usually, no serious harm will come to a male placed with a stranger female for breeding, but one should keep an eye open for signs of serious fighting.

Cages—Plastic box-type cages are very suitable for mice and are preferable to those made from metal or wood. A cage measuring $17\frac{1}{2}$ x 11 x 5 in. is large enough to be used as a stock cage or as a harem cage containing up to four females and one male. The standard size mouse box measures about 12 x 6 x 5 in. This can house a breeding pair and litter. It is convenient for large-scale breeding where space is limited, but it is rather small for classrooms where small numbers of mice are to be kept chiefly for observation.

Mice can squeeze through small apertures. The bars of a mouse cage should be no more than 5/16 in. apart.

Bedding and nesting materials—Sawdust is not very absorbent and smells from urine soon become noticeable. Sterolit is a better bedding material for mice, since it is highly absorbent and delays decomposition of waste matter.

Cleaning—Follow standard cleaning procedure (pages 23-25). It is usually necessary to clean out mouse cages at least once a week, and bedding more frequently if sawdust is used. Paper wool, wood wool, wood shavings, paper towelling, and cotton wool are suitable for nesting.

Food and water—The wild house mouse is omnivorous whereas the laboratory bred animal thrives on a herbivorous diet such as the pellet Diet 41B. Alternatively, mixed grain containing wheat, oats, and sunflower seeds is quite satisfactory. Small amounts of fresh vegetable are appreciated.

Water should be supplied in a water bottle.

Breeding—In male mice the genital opening is farther from the anus than in females of similar age and this is the simplest method of sexing. Mice may become sexually mature in 6 weeks. Ten weeks is a suitable age to start breeding, and 12 months is the usual maximum breeding age. The oestrous cycle takes about 5 days. The gestation period is 19-21 days, and the litter size usually ranges from 8 to 11. The young are born naked and blind, but develop quickly. If a harem system is employed, other females may suckle the young. The babies may be weaned at 21-28 days. The female comes on heat shortly after giving birth and mating usually occurs at this time if the male is present. In this event the fertilized eggs are not immediately implanted in the uterus so the next batch of young are not born for about another 26 days.

Sources

Mice are included in the accreditation scheme run by the Medical Research Council's Laboratory Animals Centre (see page 15). Good quality stock can be purchased from any accredited breeder.

THE ALBINO RAT (*Rattus norvegicus albinus*)

Origin

The albino rat, the most commonly used laboratory mammal, is descended from the brown rat (*R. norvegicus*), which was introduced to Britain in the 18th century. The other British species is the black rat (*Rattus rattus*), which has lived here since the 11th century. Colour differences are not a good guide to their identity, since there is much variation in both species. The black rat is the smaller of the two and these days is virtually confined to ports, having been supplanted elsewhere by the more successful brown rat.

Most people express their dislike of rats and associate them with filth and sewers. F. Howard Lancum does not exaggerate when he states:

'The brown rat is one of the most formidable menaces to our agricultural and industrial welfare. Its extermination would be hailed with satisfaction by the entire population of this country, and the man who could devise a means whereby it could finally be removed from the list of British fauna would render the nation a service beyond measure.'

To the non-scientist it must seem strange to hear of rats being bred in huge numbers and receiving the best of care and attention in scrupulously clean surroundings. When a scientist writes, 'This docile and lovable animal has been studied in far greater detail than any other laboratory species' (G. Porter 1957), he expresses sentiments which are not unusual in those who work with the albino rat. Few species are more lively, intelligent, and so responsive to proper treatment. If we can come to terms with our inhibitions and remember the benefits that have accrued to man through research involving animals we are more likely to approach the possibility of keeping rats in schools with an open mind.

Habits

The brown rat is found in all parts of Britain, in buildings and other man-made structures, and in open country. It commonly makes burrows and moves about along well defined pathways in search of food. Rats are creatures of habit and are very suspicious of any change in their surroundings. For this reason, trapping techniques have been devised involving a preliminary period of several nights when the trap is baited but not set. This accustoms the rats to the new object gradually, and after a few nights they learn to come for the bait.

Plate 1 (*right*). Zebra finches, a good species for the beginner. *Photo, H. Lacey.*

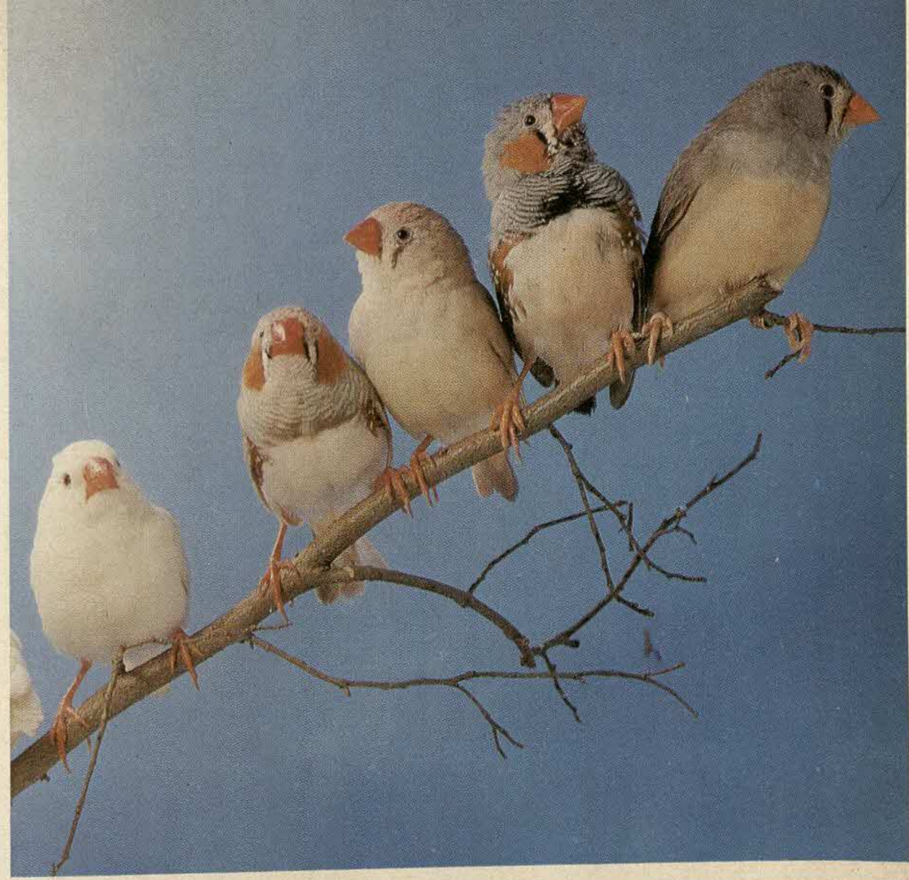
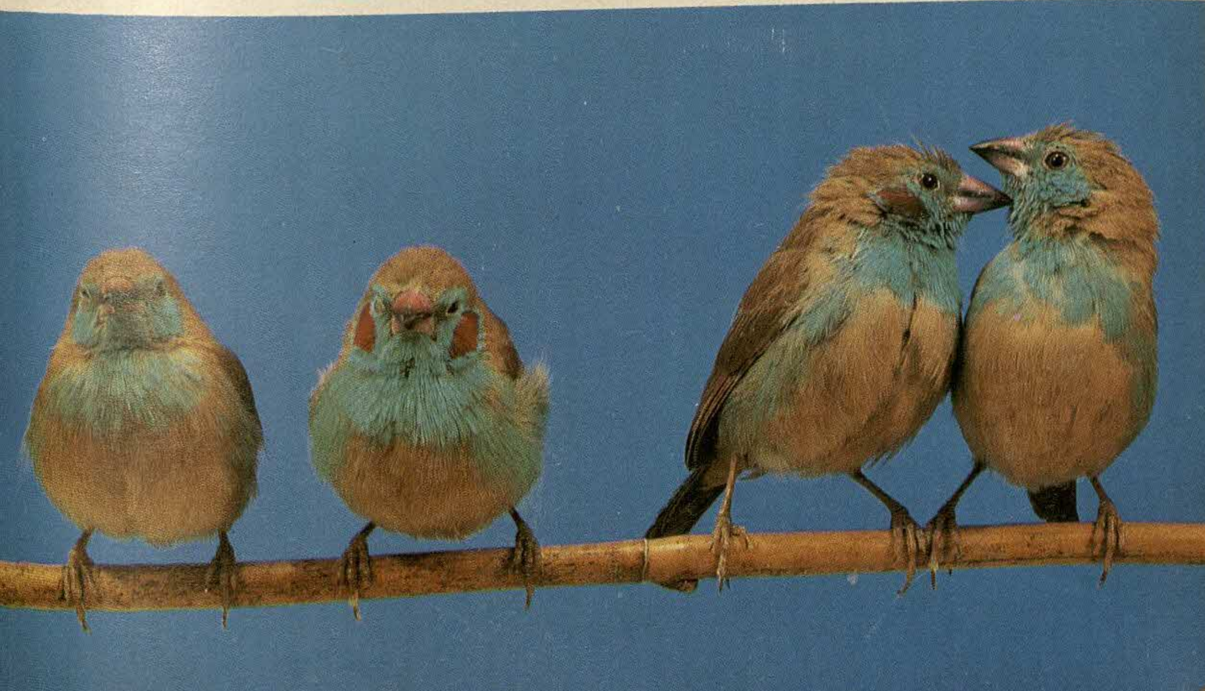


Plate 2 (*below*). Cordon bleu finches are quite hardy after acclimatization but acclimatization itself is not easy, so it is best to purchase them at the end of May. *Photo, H. Lacey.*



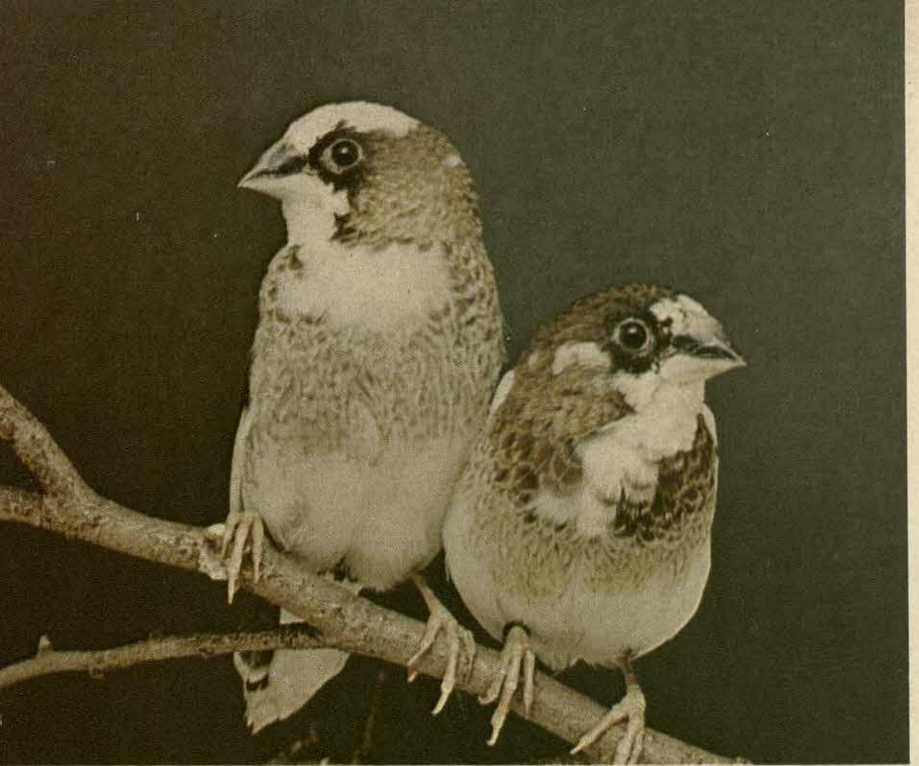


PLATE 3 (*left*). Bengalese finches have been kept as cage birds in the Far East for hundreds of years. They have no wild counterpart and are thought to have come into existence through a fertile hybrid or possibly a mutation. They are sold in the United States as 'society finches'. *Photo, H. Lacey.*

PLATE 4 (*below*). Male common frog (*Rana temporaria*). The strong colouring is caused by a recent change of skin. *Photo, H. Lacey.*

The black rat seems to be more confined to buildings than the brown. It is also the rat found on ships. Although both types are susceptible to bubonic plague, the black is much more so than the brown. The 'Black Death' and the 'Great Plague' were probably both spread by black rats.

Both species are nocturnal and omnivorous. They breed rapidly although less continuously than the laboratory rat, probably because the latter is kept in reasonably stable conditions with abundant food and water.

The laboratory rat is a friendly, inquisitive, active animal. It thrives on a herbivorous diet and breeds throughout the year. The albino variety with white fur and pink eyes is the commonest type. Hooded rats are an attractive alternative. This animal has a black head, black eyes, and a white body.

Management in captivity

Handling—A well known method is to place the palm of the hand across the animal's back with thumb and forefinger around the neck. The other fingers support the belly gently, but firmly. Alternatively both hands can be used to scoop up the animal.

Compatibility—Albino rats show very little aggressive behaviour to one another, though youngsters often engage in horseplay. Consequently males and females may be kept together in any combination according to the limitations of space in the cage, and the control of breeding. Generally speaking, rats thrive better and are more docile when kept in pairs or groups.

Cages—Because the rat is an active animal, the larger cages are better. For school use, a desirable minimum size cage is 18 x 12 x 9 in. This is large enough for a female and her litter, or not more than four young animals. Groups of young rats are better in larger cages about 30 x 18 x 12 in. Cages with $\frac{3}{8}$ in. mesh floors are suitable for rats, except the pregnant female who should be provided with a solid partition covering at least one-third of the cage floor. Solid floored cages are also suitable, particularly if a highly absorptive bedding such as Sterolit is used.

Bedding and nesting materials—Trays beneath mesh floored cages should contain sawdust, peat, or Sterolit. The same materials are suitable as bedding in solid floored cages. The usual nesting materials such as paper wool, wood wool, or cotton wool are all suitable. The pregnant female, in particular, should have a liberal supply of nesting material.

Cleaning—Standard cleaning procedure as outlined on pages 23-

25 should be followed. The frequency of cleaning depends on several factors such as cage design, type of bedding, and the number of rats in the cage. Once or twice weekly is usual. A cage containing a female and young should not, however, be cleaned during the first week after birth.

Food and water—A standard rodent pellet diet such as Diet 41B is a very good basic diet. Alternatively, a mixed grain diet is quite suitable. Both are best supplemented with fresh vegetables and, for the nursing female, fresh milk.

Water is most conveniently supplied in a water bottle, preferably of 20 oz capacity, since rats drink quite a lot.

Breeding—Rats can be sexed from birth onwards by a comparison of the distance between the anus and genital aperture, which is much greater in the male. At birth, it averages 2·8 mm in the male and 1·2 mm in the female, while at 42-50 days the average distances are 21·0 mm in the male and 13·0 mm in the female (Farris 1950).

Rats usually reach sexual maturity at 2 months. The suggested minimum breeding age is 10-11 weeks. It is not advisable to use rats for breeding after they are 15 months old. The female's oestrous cycle takes 4-5 days. The gestation period is 20-22 days. The average number of offspring in a litter is 10. Since the young are born without fur, it is easy to distinguish the sexes. The best method of examining the young is to wait until the female leaves the nest, then remove her to another cage for a short period. The young must, of course, be handled with great care and as little as possible. It is best to wait until they are about a week old before taking them out of the nest for weighing. They should be weaned after 22-30 days. General practice is to separate the sexes at this time and rear the rats in two groups.

The simplest breeding system is to place the female in the male's cage for a week or until she shows obvious signs of pregnancy, such as a marked increase in weight and enlargement of the abdomen. She should then be transferred to a clean cage with a liberal supply of nesting material, where she will have time to settle down and make a nest before her litter is born. Fresh milk, as well as water, should be provided. It is possible to leave the male with the female throughout pregnancy and birth although this may disturb the female to such an extent that she eats her litter. Another system is to have a harem with one male and several females in a large cage. The male is removed when the females show signs of pregnancy.

The female comes on heat shortly after birth of her litter and the male will mate with her, if permitted. This second pregnancy is longer; the second litter is born some 30 days or so after the first.

Sources

Rats are included in the accreditation scheme run by the Medical Research Council's Laboratory Animals Centre (see page 15). Good quality stock can be purchased from any accredited breeder. Teachers are advised to make use of this service since rats can carry several diseases which are transmissible to humans.

THE GUINEA PIG (*Cavia porcellus*)

Origin

When the first Spanish explorers arrived in South America in the early 16th century they discovered guinea pigs, already domesticated, in the homes of the Andean Indians. There are several wild species in South America, but it is not certain which is the ancestor of the domesticated guinea pig. The guinea pig was brought to Europe a short time afterwards. It was reared here as a pet. It was not used as an experimental animal until the late 18th century. Guinea pigs have three types of coat, classified as smooth-coated English, a short-haired type; Abyssinian, with rosettes of short hair; and Peruvian, with long silky hair. The first and second varieties are more suitable for school use. They are available in several different colours.

Habits

Little is known of the habits of the wild guinea pig. The wild ancestor was probably a surface-dwelling animal which lived in shallow burrows in the undergrowth of rough grassland. They are gregarious, moderately diurnal, and herbivorous.

Management in captivity

Handling—The guinea pig is a rather shy animal. Gentle handling without excitement is very important. Small children will need to use both hands. They should be taught to lift the animal around its

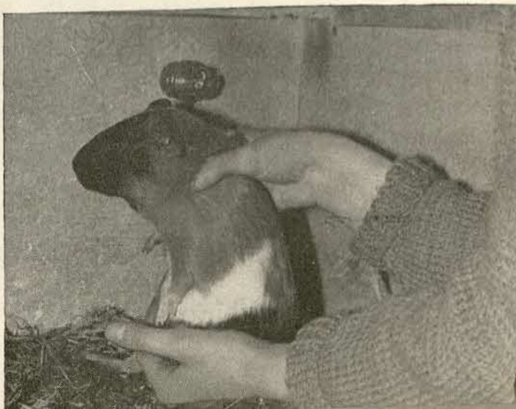


Fig. 17. Picking up a guinea pig.

chest and to transfer it immediately to a cradled position in the arms. Adults and older children can pick up a guinea pig with one hand placed across the back, immediately behind the head, but the rump should be supported with the free hand (figure 17). Females carrying young should be handled as little as possible, particularly towards the end of pregnancy.

Compatibility—Pairs or a buck and several does can be left together for life. Bucks sometimes fight with each other. They should be housed separately. An established colony in a cage may resent the introduction of a newcomer.

Cages—Guinea pigs are moderately hardy. They may be kept in weather-proof hutches out of doors. These are generally made from wood, which is a good insulator but difficult to clean. Sheet asbestos sealed with polyurethane varnish might be satisfactory for outdoor hutches. Sealing compounds might also be applied to wood. When keeping guinea pigs outside one must provide lots of nesting material, such as hay, so that the animal can make a cosy nest. The hutch should have an overhanging roof to prevent rain from entering through the front. Hutches with an attached pen standing on grass give the animals much more space. Guinea pigs are more likely to suffer from heat stroke than cold. The hutch should be placed in a shady position. A sustained temperature higher than 25°C can cause the animals difficulty, especially when the humidity is high. Pregnant females are particularly sensitive in hot weather.

Indoor cages of many different kinds are available, but satisfactory types tend to be expensive. A suitable size for school use is 24 x 18 x 12-15 in. A cage rather smaller than this, down to say 18 x 12 x 8 in., is just about large enough for one adult, but it is cramped for a breeding pair or a sow and litter. A well designed cage should protect guinea pigs from draughts. The cage should have a removable mesh floor. The mesh size in common use is about $\frac{5}{8}$ in. square. Mesh measuring 3 x $\frac{1}{2}$ in. is better still. Experience shows that the guinea pig can withdraw its foot from mesh of this size should it slip through the bars. With a smaller mesh the foot is more likely to become caught (Lane-Petter 1963). Most of the droppings and virtually all the urine pass through the mesh into a tray beneath. This arrangement helps to keep the guinea pig clean and to some extent prevents soiling of the hay, which all guinea pigs require for food. However, hay inevitably covers some parts of the mesh and retains waste matter. If hay is placed in overhead racks it is pulled down by the animals and scattered over the floor. Therefore the guinea pig cage should be cleaned out at fairly frequent intervals—probably twice a week. Guinea pigs should not be transferred abruptly from solid floored cages to the mesh bottomed type. It is best to rear them on one type or the other as soon as they are weaned. If adults have to be transferred it helps to scatter copious supplies of hay over the mesh floor. By the time this is eaten and the mesh exposed the animals have become accustomed to walking on the mesh. A pregnant female will have her litter on wire mesh, but it is usual either to move her to another cage or to fit a solid false floor over at least a third of the mesh floor. Some types of cage are so designed that the mesh floor can be removed for the female to walk directly on the bedding in the tray. This should be clean sawdust, peat, or Sterolit. Table 4 (page 70) compares some commercially made guinea pig cages. See pages 42-3 for details of how to make home-made guinea pig cages measuring 24 x 18 x 12 in.

Bedding and nesting materials—It is not the usual practice to provide nesting material for guinea pigs unless they are kept out of doors, especially when the animals are on a mesh floor where nesting materials may interfere with the free passage of faeces and urine into the tray beneath. The hay which is given as food is scattered round the cage by the animals. This may serve as temporary nesting material. It does not seem necessary to give extra nest material to a pregnant female. The young are born with a good coat of fur and come to no harm if they are not subjected to extremes of temperature.

The usual bedding material for mesh bottomed cages is peat. Sawdust is less satisfactory since it is not so absorbent.

Cage cleaning—If the animals are housed in solid floored cages with sawdust bedding, cages should be cleaned about every four days. If cleaning is delayed for much longer than this the bedding becomes rather wet and obnoxious. Cages with mesh floors should be cleaned weekly. Guinea pigs produce copious amounts of waste; regular thorough cage cleaning is essential.

Food and water—Guinea pigs are herbivorous. They require a good deal of roughage in their diet. They also need greater amounts of vitamins C and E than other rodents. Fresh green food is essential. The basic diet can be pellets of the type SG1 (see page 21) supplemented by fresh greens such as lettuce, cabbage, dandelion, clover, carrots including the tops, and good quality meadow hay. Meadow hay is especially important. Besides supplying roughage, it contains an unknown but essential factor. Mouldy hay and hay containing thistles should be avoided. Guinea pigs cannot gnaw pellets through the bars of a wire mesh food hopper. They crunch rather than gnaw

TABLE 4 **A comparison of some manufactured cages for guinea pigs**

Reference	Dimensions	Other Details	1966 Prices
			£ s d
Roe. G. type	$18 \times 13 \times 6\frac{3}{4}$ in.	Polypropylene box-type, galvanized top, 2 interchangeable internal-type hoppers for rat and guinea pig. Solid floor.	3 13 6
NKP GP2	$18 \times 13 \times 13$ in.	Polypropylene box-type, zinc-plated top with large internal-type food hopper. Solid floor.	3 15 0
AC Type 4	$20 \times 12 \times 10$ in.	Polypropylene box-type, galvanized top, 2 interchangeable internal-type hoppers for rat and guinea pig. Solid floor.	4 3 6
AC Type 4	$20 \times 12 \times 10$ in.	Polypropylene box-type, as above with removable mesh floor, $3 \times \frac{1}{2}$ in. mesh.	4 17 3
AC Type 4	$20 \times 12 \times 10$ in.	Makrolon, galvanized top, 2 interchangeable internal-type hoppers for rat and guinea pig. Solid floor.	5 18 6
NKP RS1	$24 \times 14 \times 8$ in.	Polypropylene box-type, zinc-plated top, wide internal-type food hopper. Solid floor.	4 7 6
NKP RAB1	$24 \times 18 \times 18$ in.	Polypropylene hutch-type, stainless steel front and removable mesh floor, tray under. External-type food hopper.	8 15 0
Bow. C11	$20 \times 15 \times 15$ in.	22 gauge steel back and sides, mesh top and part front. External-type food hopper, $\frac{1}{2}$ in. mesh floor, 2 in. deep tray.	7 0 0
Nat. I. R.B.	$21\frac{1}{2} \times 14\frac{1}{2} \times 14\frac{1}{2}$ in.	20 gauge steel, 6 in. high on back and sides, 3×1 in. mesh elsewhere. External-type food hopper, $\frac{5}{8}$ in. mesh floor, $3 \times \frac{1}{2}$ in. mesh floor available, $1\frac{1}{2}$ in. deep tray.	6 0 0
Wool. RC5	$24 \times 18 \times 18$ in.	22 gauge steel back and sides, mesh top and front. External-type food hopper, $\frac{5}{8}$ in. mesh floor, $3 \times \frac{1}{2}$ in. mesh floor, available as alternative at no extra charge, drawer-type tray.	7 0 0

Key	AC	Associated Crates Ltd., Coronation Street, Stockport.
	Bow.	E. K. Bowman Ltd., 34 Holmes Road, Kentish Town, London NW5.
	Nat. I.	National Iron and Wireworks Co. Ltd., Factory Lane, Blackley, Manchester 9, Lancs.
	NKP	North Kent Plastic Cages Ltd., Home Gardens, Dartford, Kent.
	Roe.	Roebuck Equipment Ltd., 685 High Road, N. Finchley, London N12.
	Wool.	All-Type-Tools (Woolwich) Ltd., Purland Road, Woolwich Industrial Estate, London SE18.

the food. Therefore guinea pig food pellets have a diameter of only 3/16 in. and are given in a specially designed hopper (figure 12). Open bowls are less satisfactory because the animals tend to foul them.

Clean water must always be available since guinea pigs drink appreciable quantities, particularly in hot weather. Open water pots soon become fouled and must be changed at least daily. Water bottles are more convenient. They should be securely fixed because guinea pigs sometimes develop a habit of shaking the spout, with the result that the bottle quickly empties. A 20 oz (500 cm^3) bottle is about the right size.

Breeding—To sex a guinea pig examine the genital region in a good light. The genital openings are about the same distance from the anus in both sexes, but the male's is round, whereas the female's is a longitudinal slit. (Lane-Petter, 1963, page 312.)

Female guinea pigs should be mated for the first time at 3-4 months of age. This enables the female to give birth to her first litter before she herself is fully grown. Under these conditions she is less likely to have a difficult birth (Paterson 1957). Females may reach sexual maturity earlier than this, sometimes when only 4-5 weeks old. The sexes should be kept separate after weaning until the females have reached the age suggested. Males develop rather more slowly although they may attempt to mate from a very early age; 3-6 months is a suitable age for a male's first mating. The breeding life of the guinea pig is 2-3 years.

Guinea pigs are unlikely to breed out of doors during autumn and winter. Indoors in heated rooms, they will breed all the year round. The guinea pig is unusual in having a very long period of gestation, averaging 63 days. The average litter size is 3 or 4. Animals are born with a good coat of hair, eyes and ears open. They can run almost immediately. They will take solid food a few hours after birth, but are still dependent on the mother's milk. The young should be weaned at 21-28 days, or when they reach a weight of about 180 grams.

If male and female are kept together continuously they may produce four litters a year for up to two years, but this would be more than most schools could cope with. The female's oestrous cycle varies from 13 to 20 days. She is on heat for about 15 hours and accepts the male once during each cycle. She shows signs of being on heat by attempting to mount the male, or another female. Apparently, guinea pigs cannot identify the opposite sex by smell. Thus males will sometimes attempt copulation with each other.

THE RABBIT (*Oryctolagus cuniculus*)

Origin

The wild rabbit has been known in Britain since the 11th century. Its domestic variety has been reared for several hundred years.

Habits

Wild rabbits are very timid. They spend the greater part of the day underground and emerge to feed in the evening and early morning. They feed on grass and many other kinds of plant materials, particularly young cereal crops. Before 1953, damage to cereal crops alone, in England and Wales, was estimated at about £15 million a year. The character of chalk downland turf was almost entirely due to the very close, heavy grazing by rabbits. The status of the rabbit as a pest second only to the rat changed dramatically with the arrival of the virus disease myxomatosis in late summer 1953. Within two years the rabbit population had fallen from an estimated 100 million to less than 5 million.

The burrow systems of rabbits may be very extensive, covering hundreds of square yards. Trees and bushes are a favourite spot for starting new burrows, probably because of the cover they afford. Does tend to make new burrows for rearing young on the outskirts of an already existing burrow system.

One of the rabbit's most interesting habits, rediscovered in 1939, is that of eating some of its own droppings to extract further nourishment from them. This process is analogous to rumination in cows. Two types of droppings are formed: soft rounded ones, which are taken from the anus and swallowed without chewing; and dry, pellet-shaped droppings, which are discarded. In domestic rabbits refection of droppings occurs at night, whereas in the wild species it is carried on both in the day when the animal is underground and also in the middle of the night when there is little activity. It is believed that refection allows greater absorption of B-vitamins formed by bacterial activity in the caecum. (Madsen 1939, and Kon 1945.)

Management in captivity

Handling—Hold the head steady by grasping the base of the ears firmly but without pulling. Place the other hand underneath the belly and lift with both hands together. To carry a rabbit, place the index finger between the ears and hold the head with the thumb and other fingers; place the other hand round and under the rump, the animal facing the handler. Rabbits should always be placed on a non-slippery surface; they may take fright if they slip. A sacking covered table is satisfactory.

Compatibility—The sexes should be kept apart except for breeding, since the female may attack the male. Groups or pairs of one sex may be kept together, provided there are no signs of fighting.

Cages—There are many varieties of domestic rabbit. They range in size from the tiny Netherlands Dwarf, which weighs about 2 lb when fully grown, to the Flemish Giant, which may tip the scales at 14 lb. The size of the cage depends upon the size of the rabbit. For school use the Netherlands Dwarf (figure 18) has much to recommend it because it is small. The following remarks are made with this variety in mind. Larger rabbits will need correspondingly larger cages.

A minimum size for a cage to hold a single adult rabbit is 24 x 18 x 18 in. A doe with a litter should have a cage measuring at least 36 x 24 x 18 in. A very useful arrangement is to have a cage of breeding size with a removable central partition so that the cage may be converted into two individual cages. Commercially made all metal cages of this size and style are very expensive, costing upwards of £12. Table 5 (page 74) gives details of some good quality all-metal cages suitable for housing small rabbits in schools. One of these is a large breeding cage. Mesh bottomed cages are satisfactory for the smaller varieties of rabbit but the larger, heavier kinds may get sore hocks on wire mesh.

Home-made cages are the obvious alternative to commercially made types and are much, much cheaper. They can be made of wood, hardboard, chipboard, blockboard, and concrete asbestos sheet. These all have advantages and disadvantages as described in table 3 (page 36). It is essential to seal the surface properly so that water will not soak in when the cage is scrubbed with hot water. An effective sealer also prevents urine from penetrating the floor of the cage. There is need for experiment here, but it seems likely that a polyurethane varnish will prove the most durable sealer. Details of the construction of a rabbit cage are given on pages 43-6.

Outdoor hutches, preferably with attached runs, are very suitable for rabbits. The hutch must be weather-proof and well insulated. For the larger varieties of rabbit outdoor housing is often the only way to provide the animals with sufficient space. Size makes the rabbit the least suitable small mammal to keep in the classroom itself.

Fig. 18. Holding a Netherlands Dwarf rabbit.

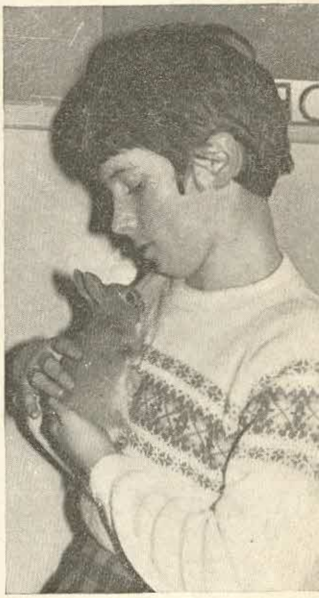


TABLE 5 Details of some manufactured cages for rabbits

Reference	Dimensions	Other Details	1966 Prices
			£ s d
Bow. C.14	24 × 18 × 18 in.	Top and part sides and back of 1 in. square mesh, lower part of back and sides of galvanized steel. Fixed mesh on either side of door to hold pellet food hopper and water bottle holder. Drawer-type tray and ½ in. mesh floor. Supplied with external fitting food hopper, 540 cm³ water bottle with nickel-plated brass spout and hanging wire.	8 8 0
Wool. RC.1	19 × 24 × 18 in.	Back and sides 22 gauge galvanized steel. Wire mesh top and full width door. ⅝ in. mesh removable floor located on fluted sides. Drawer-type tray, external fitting pellet food hopper and wire bottle holder. Water bottle extra.	6 10 0
AC Rabbit-cage	40 × 24 × 15 in.	Back and sides from 18 gauge galvanized steel. Top and front 3 × 1 inch 12 gauge mesh on 5/16 in. frame. Two doors, centre space for partition to convert into 2 cages. Space for 2 hoppers. Base 3 × ⅝ in. mesh. Tray beneath. Hoppers 27s each, water bottle holders 3s 3d each. Price including tray, 2 hoppers, and 2 water bottle holders. Partition extra.	14 19 3

Key	AC	Associated Crates Ltd., Coronation Street, Stockport.
	Bow.	E. K. Bowman Ltd., 34 Holmes Road, Kentish Town, London NW5.
	Wool.	All-Type-Tools (Woolwich) Ltd., Purland Road, Woolwich Industrial Estate, London SE18.

Bedding and nesting materials—Solid floored cages should have a liberal covering of sawdust. Other bedding materials are likely to prove too expensive for use in these large quantities. Hay is commonly used for nesting material. It is very suitable so long as it is clean and dry.

Cleaning—The standard cleaning procedure outlined on pages 23-25 should be followed. The largest cages cannot be immersed in disinfectant. They should be scrubbed with water containing disinfectant, rinsed, and allowed to dry. Soiled sawdust should be swept out about every other day. The floor of the cage should be scrubbed weekly, and the whole cage once a fortnight.

Food and water—The pellet diet called SG1 (page 21) is a suitable basic diet for rabbits. It is best dispensed either in a food hopper or a heavy bowl with an inrolled margin to prevent spilling. Fresh green vegetables, carrots, dandelion, and clover leaves are useful supplements. Clean water should always be available, preferably in a large water bottle, approximately 20 oz capacity, with a plated brass spout.

Breeding

To sex a rabbit, hold the animal upright with the legs facing away from the handler; stretch the skin slightly in the genital region. The genital aperture of the male is round, while that of the female is a longitudinal slit. The ano-genital distance is rather greater in the male than in the female.

Small varieties of rabbit become sexually mature at 4-6 months, but it is wise to defer mating until the animals are 6 months old. Larger varieties mature at a later age. Generally speaking, the smaller varieties of rabbit are not used for breeding after they are two years old.

Although it is often stated that there is no definite oestrous cycle in the rabbit, it now seems likely that there may be. It has been suggested by Templeton and Kellog (1959) that there is a 15-16 day oestrous cycle and that conception can occur between day 2 and day 14 of this cycle. There is no reliable method of telling whether or not a doe will take the buck. If the doe's vulva is swollen and moist she will usually mate; but the absence of this sign does not necessarily mean that she will not mate (Lane-Petter 1963).

The doe should be introduced to the buck's cage. If they are in good breeding condition, mating will occur almost immediately. The stimulus of copulation causes the release of eggs from the ovaries of the female about 10 hours later. The gestation period is about 30 days. Small varieties of rabbit tend to have smaller litters than the bigger varieties. The average is 4-6.

Nest boxes are useful since they help keep the young warm, and they help to keep them in the nest. A nest box lined with sawdust and hay or straw chopped into 6 in. lengths should be placed in the doe's hutch about a week before the litter is due. The doe should not be disturbed until the young start to leave the nest and take solid food—usually at about 21 days. The usual weaning age is 8 weeks, when the young should be separated into single sex groups.

Sources

Rabbits are included in the accreditation scheme run by the Medical Research Council's Laboratory Animals Centre (see page 15). Good quality stock can be purchased from any accredited breeder.

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Chapter 2

Foreign finches

Introduction

KEEPING A FEW foreign birds for the pleasure they afford can be a simple hobby which demands little of one's time. It is true that what starts in a small way can quite easily develop into an all-absorbing passion, but teachers, who have many demands made on their time, will be relieved to know that no great technical knowledge is needed to keep birds successfully. The following notes will give useful guidance to the beginner, but the best advice is to watch the birds carefully, learning their normal habits so that unusual behaviour, which might be due to an ailment, is soon spotted and acted upon.

PROBLEMS OF CONSERVATION

A natural first question is, 'Why keep birds in captivity at all?' There has, in recent years, developed a considerable traffic in the importation of exotic creatures, including birds. We would not wish to encourage this traffic in any way because there have been instances of needless suffering caused to birds and other animals through the ignorance of some importers. Moreover, there is also a conservation problem. The large-scale trapping of birds and other animals for commercial purposes is to be deprecated. There are many examples of the effects of over-collecting of species in this country. Foreign species are no less vulnerable.

Perhaps there is a positive answer to this problem. We suggest that teachers obtain tropical birds from breeders rather than importers, and ask for specimens bred in this country. There are several species with a long history of successful breeding in Britain and these are the ones we would particularly recommend. Apart from the fact that, by doing this, we should not be robbing another country of its fauna, we shall obtain birds which are used to the British climate and known to thrive here. When we explain our actions to children, we may make a significant contribution to the conservation principle by influencing the general public of tomorrow.

SOME POSSIBILITIES FOR STUDY INVOLVING BIRDS

Children can see many aspects of bird life and behaviour in a cage or aviary containing a few tropical birds. Some pupils will learn to distinguish individuals of the same species by making careful observations of differences in colour, shape, song, and behaviour. Questions concerning feeding habits may arise, such as food likes and dislikes, amounts of food eaten, frequency of feeding, method of feeding, etc. The question, 'What does our bird weigh?' taxed the ingenuity of one group of ten-year-olds who eventually made a perch which was also a weighing device. Birds in outdoor aviaries are affected by the weather conditions, and children, through observation, gather much experience of short term and long term climatic effects. Beaks, claws, wings, and flight are traditional subjects of study associated with birds: an approach which gives added meaning and interest is to compare these things in several different species. Bird song can be an interesting starting point with many possibilities, from sounds and recognition to tunes, music, and sound production.

Observation of breeding behaviour may stimulate pupils to study plumage, nest building, breeding song, feeding of young, courtship display, growth and development, and so on.

Some of the observations and investigations will reveal problems which cannot easily be answered by experiment. Here there will be a need for reference books and other sources of information. The bibliography at the end of this chapter includes some books which children have found useful in supplementing their own observations.

Obtaining birds

PURCHASING

As explained in the introduction on page 78, it is best to buy from a breeder, who is almost certain to be knowledgeable and willing to advise a beginner. There are several cage bird societies which supply details of reliable breeders, and beginners should seek advice before making a purchase. Information about these societies can be found in the journal *Cage and Aviary Birds* available from most booksellers. If possible, choose a local source of birds and try to arrange a visit to the breeder's aviaries. Most are glad to give advice and some will receive a small school party. Bright, clear eyes are a better indication of good health in a bird than the condition of the plumage. Avoid a listless bird which sits puffed up or with its head under its wing. If the feathers around the vent are soiled with excreta the bird is probably suffering from an intestinal infection.

Late spring and summer are the best times to buy birds, especially if they are to be housed in outdoor aviaries, because they will have a long period of mild or warm weather during which they can become acclimatized. There is something to be said for ordering the birds some time before they are required since this helps the breeder plan his breeding schedule and enables him to supply young birds.

There are several factors to consider in deciding on the number and variety of birds to buy. The size of cage or aviary is obviously a limiting factor. One might keep two small finches of the same sex in a cage measuring 24 x 12 x 12 in., but a cage of this size is rather too small for breeding. A sensible first cage is that known as a 'double breeder'. This measures about 36 x 12 x 12 in. and has a removable partition which can be used to divide the cage into two halves, each about 18 x 12 x 12 in. This cage is large enough for one breeding pair and their young or four non-breeding adults. If the birds are allowed to continue breeding, either extra accommodation must be found or the surplus birds removed. Some breeders are prepared to take back surplus young birds, but it is as well to check on this at the time of first purchase.

Another factor to bear in mind when building up a collection of birds is compatibility. In an aviary where the birds have much more space, a variety of birds will live peacefully together, but in a smaller enclosure there is bound to be some competition and fighting. As a general rule one should not keep more than one pair of the same species in a cage or small aviary, because the males fight over the females and all the birds compete for nesting sites and materials.

For example, the zebra finch (*Taeniopygia castanotis*), which you can see in plate 1, is one of the best species for the beginner; it is easy to breed and mixes readily with other species. However, two pairs of zebra finches kept in a small cage are likely to quarrel.

There are some exceptions to this rule, notably the fire finch (*Lagonosticta senegala*), and the cordon bleu (*Uraeginthus bengalus*)

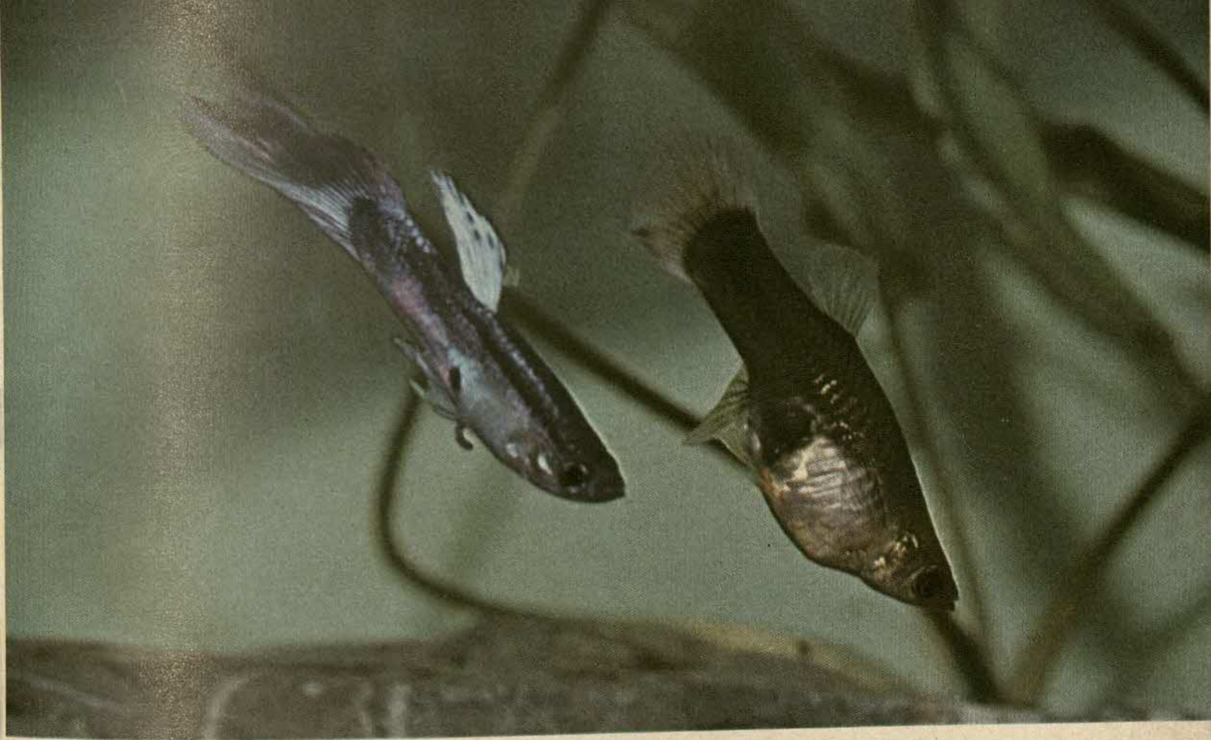
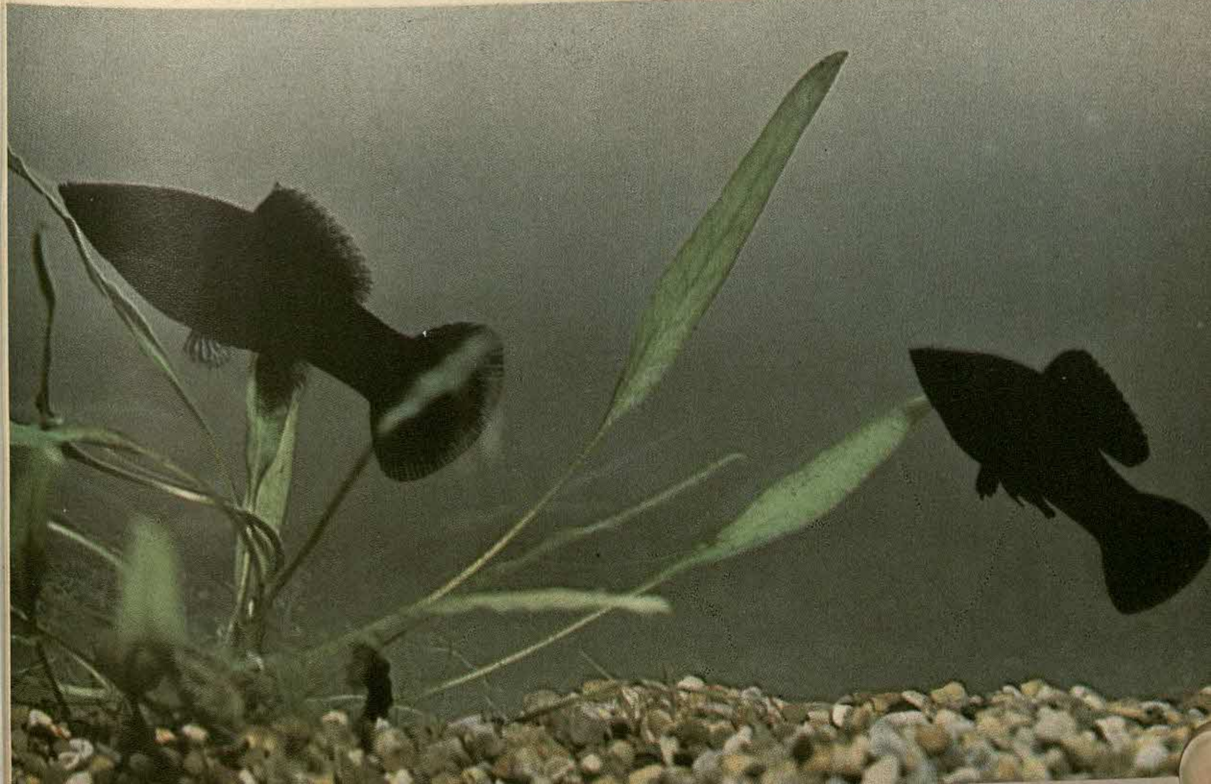


PLATE 5 (*above*). A pair of guppies. The male is on the left.

PLATE 6 (*below*). Black mollies.



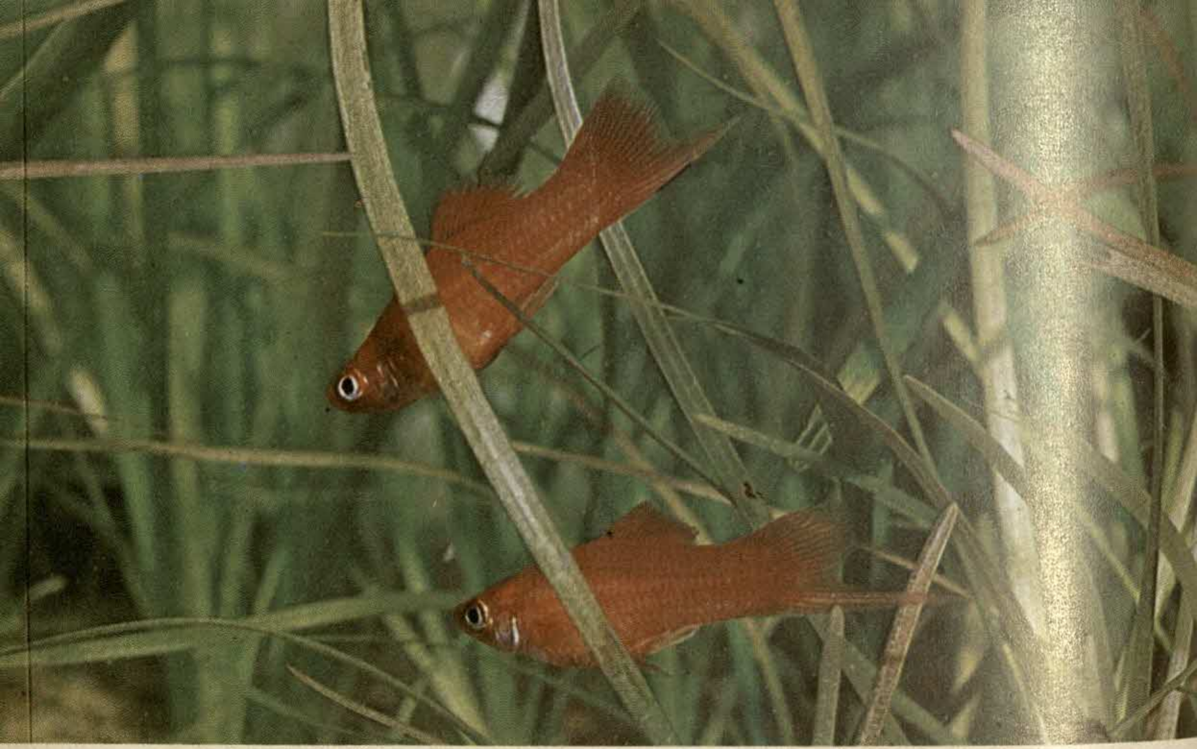
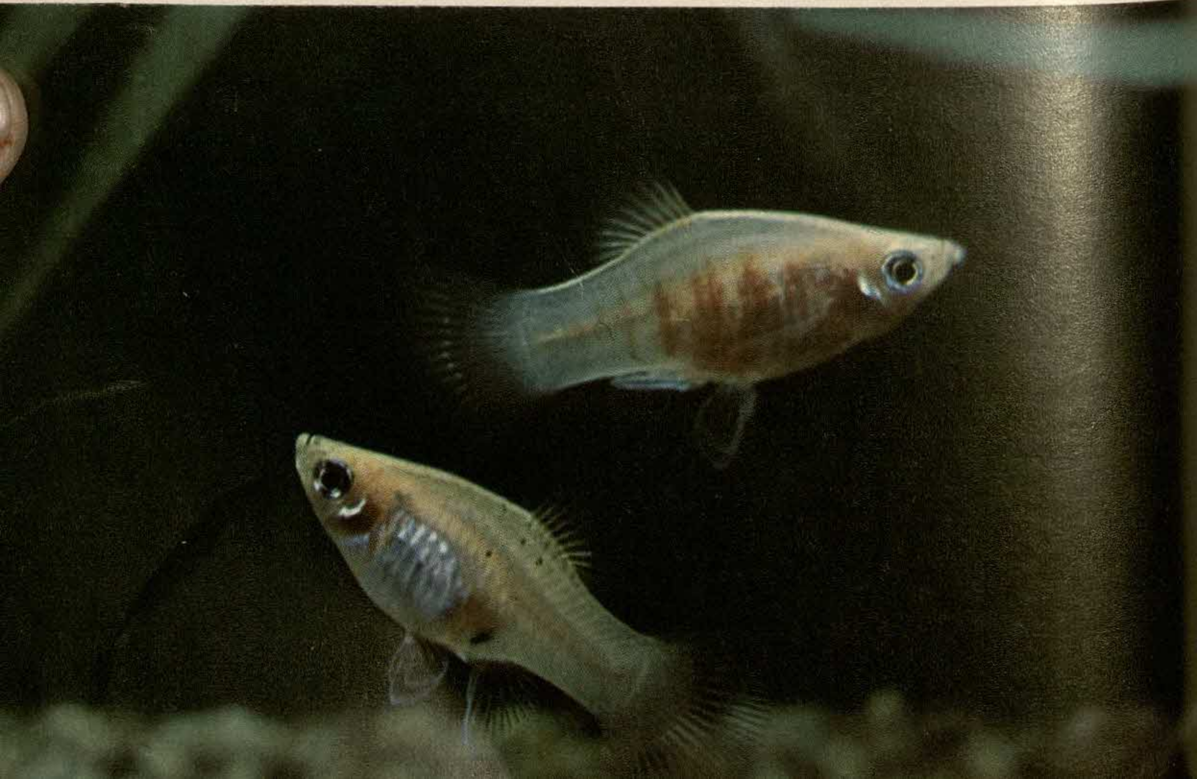


PLATE 7 (*above*). Red swordtails.

PLATE 8 (*below*). A pair of platy fish.



which is shown in plate 2. Both of these may be kept in mixed or single species colonies: these birds are therefore very suitable for school use. Another easy species is the Bengalese finch (*Munia striata*), a S.E. Asian cage bird, probably of hybrid origin. This may be reared without difficulty in single species colonies. Indeed, it is so lacking in territorial aggression that some experts advise that it should be kept separate from other species. (See plate 3.)

The canary is another suitable species for the beginner, but it is larger than the other finches mentioned and should be kept separately. The budgerigar is another pugnacious bird which should not be housed in the same cage as smaller species.

The beginner is advised to make a start with one or other of the above-mentioned species, which are all generally available, being bred in this country. See also the lists on pages 96 and 97, for further details of certain species.

TRANSPORTING BIRDS

Ventilated cardboard boxes are commonly used to carry birds over short distances. Those who can collect the birds personally may prefer to make a special travelling cage. During a long journey the birds should have access to food and water, the latter in a tin three-quarters filled with cotton wool or moss to prevent spilling. If the birds have to be sent by rail it is best for them to make the journey overnight when they are less active and require smaller amounts of food and water.

DEALING WITH NEW ARRIVALS

The first birds kept by the beginner can be put in their permanent quarters immediately, but a careful watch should be kept, particularly during the first fortnight, for any signs of ill health. Birds which show any signs of being off colour (see page 88) should be removed to another cage. The beginner may not have another cage, and it may be necessary to adapt a tea chest or soap box as a hospital cage (page 88). When, at a later date, further additions are made to the collection, the newcomers should be kept in a separate cage for two to three weeks until it is certain that they are in good health.

When a new bird is put into a cage or aviary that already contains birds, an extra dish of food should be put out in a conspicuous position. Established birds are inclined to be aggressive at first to newcomers and tend to guard their established food pots jealously. An extra pot gives the newcomer a chance to feed and settle in. Some new birds are not used to food hoppers so it is wise to have an open pot of seed at first, until the bird has picked up the habit of feeding from the hopper.

If a new bird arrives in the evening it should not be placed in an aviary, because it may not find food before nightfall. Instead keep it in a cage overnight, leaving an electric light on for a few hours so that the bird can find food and water.

Management in captivity

HANDLING

In general, the less a bird is handled the better. Small birds are particularly susceptible to shock. New arrivals can usually be introduced to their new quarters by opening the travelling box inside the cage. When transferring birds from one cage to another it is usually possible to place the two cages side by side with the doors together and gently drive the bird from one to the other. To catch birds in an aviary, place a butterfly net quickly over the bird as it lands on the wire mesh.

To hold a bird in the hand, gently manœuvre it into a convenient position and grasp it firmly but gently, with the neck between first and second fingers and the thumb over the back. It helps to remove all perches from a cage before attempting to catch a bird. It is essential not to squeeze the thorax and abdomen.

HEAT AND LIGHT REQUIREMENTS

Recently imported birds must be gradually acclimatized to the British climate, particularly if they are to be kept out of doors. This is less of a problem if birds are purchased in late spring or summer. Cages should remain indoors in a warm room until the night-time temperature outside does not fall below 10°C. It is wise to provide a simple heating arrangement in the form of a tubular heater inside the shelter of an outdoor aviary so that the temperature during the winter can be maintained at 10°C or higher, not falling below 7°C. The heater must be covered with a protective screen of perforated zinc or similar material so that the birds do not burn themselves.

During the winter, birds housed in outdoor aviaries should be shut in the shelter on cold days and at night. The birds soon become used to a routine and fly into the shelter when their keeper approaches. Acclimatized birds tend to decide for themselves whether it is warm enough to venture out of the shelter into the flight. A bird when cold or sick fluffs out its feathers and looks miserable.

The requirements of birds for light are satisfied if, within the cage or aviary, they have a choice of light and shade. The light may be sunlight or artificial light, but there is no need to keep electric lamps burning whenever the sun goes behind a cloud! An aviary is well placed if it receives morning sunlight.

SITUATION OF CAGES AND AVIARIES

A good site for an indoor cage is on a table at right angles to a south-facing window. In this position part of the cage receives sunlight and part is in the shade. Moreover, anyone approaching the cage will not throw a shadow over it which might scare the birds.

Outdoor aviaries are best in a sunny position but there should be one part of the aviary which is shaded to give the birds a choice of conditions. An exposed site should be avoided and it may be necessary to erect woven fencing to give some shelter from winds.

FOOD

Aviculturists use the term 'hardbill' to describe small, predominantly seed-eating birds such as finches, sparrows, and cardinals, which crack open the seed with their short, conical beaks, discard the husk, and eat the kernel. Hardbills, it should be noted, do also eat small quantities of insect food. The term 'softbill' refers to birds which feed mainly on insects, fruit, and nectar. This type of bird is not dealt with in this account since the provision of quantities of insect food for the whole year is difficult.

Pigeons, doves, and quail have yet another feeding habit, for they swallow seeds whole. Although these species are easy to keep in captivity we should point out that they may be carriers of psittacosis or ornithosis, a disease communicable to man, so teachers should be particularly careful about obtaining healthy birds.

The staple diet of canaries and other small finches is seed, but this should be supplemented by insect food. Some types of seed are particularly rich in fat while others contain a high proportion of carbohydrate. A mixture of two parts by weight of canary seed (carbohydrate rich) and one part rape seed (fat and protein rich) does well for canaries and is satisfactory for other small finches. Millet has a similar food value to canary seed and the yellow variety could be mixed with canary seed or used as an alternative. Some varieties of rape seed are 'hot' to the taste and birds may not accept them. The best type of rape seed is the so-called German summer rape or Rubsen rape which is a 'cold' rape. Some breeders prefer to give their birds a free choice of several types of seed, each in a separate pot, arguing that the bird will take an appropriate amount of each. This method works well, provided the range of seeds includes carbohydrate rich, fat rich, and protein rich types.

Naturally, if a bird is very hungry it may eat a type of seed it would not normally accept. On the other hand, when birds are given a mixture of seeds there is no guarantee they will eat the seeds in the same proportion as in the mixture.

Variety can be given to the seed diet by providing small quantities of such seeds as sunflower, hemp, linseed, niger, and teazle. However, these should be given sparingly until the rearer has sufficient experience to gauge the health of his birds. Yellow millet sprays and seeding heads of common grasses, thistles, clover, plantains, and so on, are also useful.

Fresh greenstuff such as chickweed, lettuce, and groundsel, should be given several times a week, being hung from the bars at the front of the cage or stood in heavy pots of water. Lettuce and groundsel have laxative properties and the latter should be given only in small amounts. Sometimes groundsel is infected with a fungus. This causes the flower stalks and main stem to swell. A white powder of spores may be visible. These diseased plants should not be given to the birds. Grass turfs are good as the bird will peck them over, eating grass and earth with beneficial effects. Other useful plants are dandelion, spinach, and cabbage. During the winter months care must be taken not to give the birds frozen green food.

Birds require small quantities of calcium to promote healthy bone growth. A piece of cuttlefish bone can be hung from the bars to provide calcium, or pieces of eggshell may be ground up and strewn on the floor of the cage among the sand.

Grit is also necessary. This is swallowed and retained in the gizzard where it helps to break up food into smaller pieces.

Live insects should be given to seed-eating birds about once a week. Mealworms and blowfly larvae can be reared for the purpose (see pages 194-8), or insects and spiders can be collected from the hedgerow (for collecting methods see page 167).

WATER

Birds need water for drinking and bathing. Shallow containers such as earthenware plant pot saucers or pie dishes can be placed on the floor of an aviary and, provided the water is changed at least once a day, will serve for both drinking and bathing. If they splash water on the floor of an indoor cage the floor becomes difficult to clean. Therefore water for drinking should be given in small pots hung on the front of the cage. The pots must be clean and the water changed regularly. A bird bath may be hung in front of the open door of a cage so that the bird steps inside and little water splashes into the cage. Such a bird bath should have a ribbed floor or rough surface for the bird to take a firm grip.

BEDDING, NESTING, AND OTHER MATERIALS

The best material for the floor of a cage is clean, dry sand. Many cages incorporate a shallow tray which can be removed for daily or weekly cleaning without much disturbance to the birds. Opinions differ as to the best bedding for an outdoor aviary. Some prefer to plant grass while others claim that a layer of sand is easier to manage since it can be raked over or completely renewed. One advantage of grass is that its seed heads are relished by many birds and form a valuable natural food. A very effective arrangement which combines the advantages of both materials is to have a sand covered floor with grass growing in a few pots here and there. These are easily replaced when necessary.

Many materials are suitable for nesting. For example, dry grass, cotton wool, felt, etc. (see page 86). Nesting boxes of varying design will also be needed if breeding is to be attempted (see page 95).

PLANTS IN AN AVIARY

The chief problem about having plants in an aviary is that their leaves become soiled with bird droppings, and if the aviary is crowded with birds the plants soon become unsightly and may even be killed. These difficulties are partly overcome if shrubs or other plants are so placed that rain can reach them and wash away the droppings. Sometimes climbing plants can be grown up the wire mesh.

CLEANING CAGES AND AVIARIES

When birds are breeding in cages the less they are disturbed the better. At all other times the cage should be cleaned regularly. It is usual to spread a thin layer of sand on the floor of the cage or in the removable tray. Sand and droppings should be removed at least once a week. A removable tray can be scrubbed and disinfected before it is replaced (for types and strengths of disinfectants see page 24). Perches should be kept clean by scraping once a week and should be scrubbed once a month. Food pots and water containers must be kept clean. It is a good idea to have a spare set and use them in rotation. The routine for all cleaning operations should be:

Remove loose debris—scrub with hot water containing detergent—rinse—soak in disinfectant or spray with disinfectant—rinse.

The most useful cleaning tools are a paint scraper, a scrubbing brush, a nylon scourer, and a dishcloth.

Outdoor aviaries must be cleaned regularly. Some aviaries can be moved from one area of grass to another. If the aviary is fixed the floor will probably be concrete with sand strewn over. The sand should be replaced at intervals depending on the number of birds in the aviary, perhaps once in two months. Any type of clean sand is satisfactory for the floor of a cage or aviary. Some breeders use sawdust, which is more absorbent, particularly for insectivorous birds which produce more liquid droppings.

BREEDING

When only one species of bird can be kept for breeding, the canary is particularly suitable because it will nest and rear young in an open nesting box, where the whole process of breeding can be seen. Most other species will not readily breed unless closed-top nesting boxes are provided in secluded positions.

Breeding birds tend to be more aggressive and allowances must be made for this when deciding on the number of birds to keep. The safest policy is to have one breeding pair of birds in a cage. The birds mentioned on pages 80-1 may be housed together and bred in an aviary, provided certain precautions are taken. It is important to have many more nesting boxes than pairs of birds, say two boxes per pair, since this will reduce bickering over nesting sites. For the same reason one should provide an abundance of clean nesting material such as fine grass, meadow hay, cotton wool, down, felt, horse hair, etc. Hair should not be more than 2 inches long, or it may twist round the birds' legs.

Small finches such as zebra and Bengalese finches breed throughout the greater part of the year and male and female should be left together continuously. Most species of small finch are ready for breeding at the age of one year. One should look out for signs of sexual activity, especially during the spring months. A pair of birds which wish to breed show a great amount of interest in each other.

The cock may feed the hen or display before her. Both are likely to search for and carry pieces of nesting material. Sometimes the signs are less obvious, but a generally increased amount of activity, together with an improvement in the birds' condition, the plumage becoming very sleek, are indicative of breeding desire. Nesting boxes and nesting materials should be supplied at this time and withheld when the aviculturist wishes to prevent further breeding. It is in the birds' own interest not to allow them to breed continuously, since the rearing of young is hard work for the parents.

Canary breeders adopt a slightly different practice. A pair, selected for breeding, is placed in a breeding cage during February. At first the two birds are separated by a solid partition across the middle of the cage. This is replaced by a wire partition after about a fortnight. When the birds begin to feed each other through the wire they are ready to mate. The partition is removed and mating allowed when a temperature of 10°C can be maintained: usually towards the end of March. Nesting materials and a nesting box are supplied.

Incubation

Most finch eggs hatch in about 12 days, the incubation period varying with the species. In general, it is best not to interfere with the birds during incubation in case they desert the nest. Canaries are an exception, though some caution is advisable even with them. It is general practice to remove the first three eggs as they are laid, replacing each with a dummy egg. The eggs are kept in a box lined with hay or wood wool at room temperature until the afternoon of the third day, when they are returned to the nest. This procedure checks the development of the first laid eggs and ensures that the complete clutch of 4 to 6 eggs hatches at the same time.

When the eggs have hatched, the birds should be disturbed as little as possible, canaries included. One can usually tell that there are young in the nest by the increased feeding of the adults, who often show a marked preference for a particular food. As the babies grow they can be heard squeaking in the nest. The young birds leave the nest and fly some two to three weeks after hatching.

Food for breeding birds

It is necessary to provide a greater proportion of insect food which the parents give to the young, particularly when they are very young. This can be supplemented with a composition 'soft food' made from hard-boiled egg mixed with breadcrumbs in about equal parts and moistened. Proprietary nestling foods are also suitable. Millet and canary seed can be germinated by soaking it for two or three days in water. This softens the seed coat and makes it very suitable for the young birds.

Young birds are usually nervous when they leave the nest and they dash about the aviary or cage, banging against the wire and sometimes falling to the ground. If any young birds are found on the floor of an outdoor aviary in the evening, they should be picked up gently and placed in the shelter where they will be safe for the night. It is not advisable to leave young birds out in the flight at night since they may catch a chill.

AILMENTS

A sick bird often puffs out its feathers and holds its wings slightly away from the body. The head feathers may be ruffled and the bird tends to tuck its head under its wing and sleep on both feet at every available opportunity. There may also be some shivering and little appetite for food. A healthy bird is alert, has tight plumage and bright eyes, and often stands on one leg.

Sickness may be due to a number of causes, and the detailed treatment differs according to the disease. We do not advise teachers to attempt specific treatment unless they are capable of carrying out an accurate diagnosis. This is more the province of the qualified veterinary surgeon and we suggest that expert advice should be sought whenever possible.

At the first sign of illness catch the bird and isolate it in a warm room, preferably in a 'hospital cage' in which the heat can be regulated. A locust colony rearing cage (see page 192) can be adapted for this purpose. A temperature of 21 to 27°C is suitable. Provide grain, water, and clean, fresh greenstuff. Keep an eye on the sick bird but disturb it as little as possible. Warmth and quiet are frequently sufficient treatment to bring about a cure. The hospital cage must be scrubbed and disinfected after use.

Good management of birds in captivity is the best way to prevent disease. This includes careful attention to diet, regular cage cleaning, and provision of appropriate living conditions, as well as obtaining stock from reliable sources. It is wise to develop the habit of looking over the birds each morning to spot any signs of illness.

One routine matter which should not be neglected is a regular examination of the birds' toe nails. If the aviary contains a variety of perches the nails will be worn down quite naturally and claw-clipping should not be needed often. Birds in smaller cages should have their claws clipped before they become so long that the bird gets caught in the wire mesh. Only the pale tips of the claws should be cut, and not the part nearer the toe, which contains blood vessels.

EUTHANASIA

If a bird is so ill that it has to be destroyed it is probably best done by a veterinary surgeon. For general information on euthanasia, see page 28.

Cages, aviaries, and other equipment

The term aviary is generally taken to mean a bird cage large enough for a man to enter, while a cage is smaller, though not necessarily very small. Usually one starts by buying or making a cage since this is less of a commitment than an aviary. Three types of home-made housing of increasing size are described on pages 90-4 to illustrate the general principles of housing birds, but there is great scope for variation to suit individual needs and constructional skills.

CAGE DESIGN

For indoor cages, those with solid sides, back, and top are preferable to open wire mesh types because they give the birds a greater feeling of security as well as reducing draughts. Some species will not breed in open wire cages. The larger cages are almost invariably made from wood with wire mesh fronts. A well designed cage will have a removable tray which slides into the base and simplifies cleaning out. A splash front up to four inches high is a useful feature since it retains sand and other debris which otherwise fall through the wire mesh. Wooden parts should be sealed with a non-poisonous paint or varnish.

CAGE SIZE

For school use, a cage measuring 36 x 12 x 12 in. is a satisfactory minimum size (see page 80). It is unlikely there will be space for anything larger in the classroom, but some schools have used parts of an entrance hall to house rather larger cages and aviaries. The latter, partly indoors and partly out, can be a most attractive feature.

HOME-MADE CAGES

The bird cage shown in figure 19 can be built quite simply using the technique described in detail below. Suitable materials include plywood, hardboard, laconite, Formica, and cement asbestos. Porous materials such as plywood and hardboard must be sealed, preferably with polyurethane varnish. Bearing in mind that standard sized sheets of most of the materials listed above are 8 x 4 ft, a convenient size for a home-made cage is one which can be cut from a 4 x 4 ft sheet with the minimum wastage. The cage illustrated has internal dimensions of 36 x 12 x 17 in. high. It is a box-type cage with back, sides, and top made from solid sheet material. The base is a removable tray which slides in runners. The front consists of a 36 x 12 in. wire mesh panel which slides in grooves. Immediately below the wire mesh is a splash front 5 in. high. It is possible to fit a removable central partition which divides the cage into two.

Construction

Mark out the sheet material, say ¼ in. oil-tempered hardboard, and cut to size, using the marking-out diagram in figure 20. Hardboard can be cut with a panel saw. Asbestos should be scored and broken as described on page 38. Trim up the edges with a large file.

Mark out the positions of the drill holes on the smooth surface of the hardboard according to the drilling diagrams in figure 20. The smooth surfaces are eventually fitted on the inside of the cage and it helps to write 'back', 'side', etc., on each sheet.

Centre punch the drill marks and drill the holes using a 5/32 in. metal drill which clears gauge 6 woodscrews.

Countersink the holes with a rose countersink bit. Some holes are countersunk on the smooth surface of the sheet material, others on the rough. Proceed as follows:

Back—All holes are countersunk on the smooth surface except the two holes on the top edge. These are countersunk on the rough surface.

Sides—The holes on the front and base edges are countersunk on the smooth surface, and the remainder on the rough.

Top—All holes are countersunk on the smooth surface.

Removable tray—All holes are countersunk on smooth surface.

Cut lengths of ⅞ x ⅞ in. planed deal to size according to the following list:

1 of 36 in.
2 of 10¼ in.
2 of 15½ in.
2 of 36½ in.
2 of 16 in. grooved as in figure 5 (chapter 1).
2 of 12½ in. grooved as in figure 5 (chapter 1).

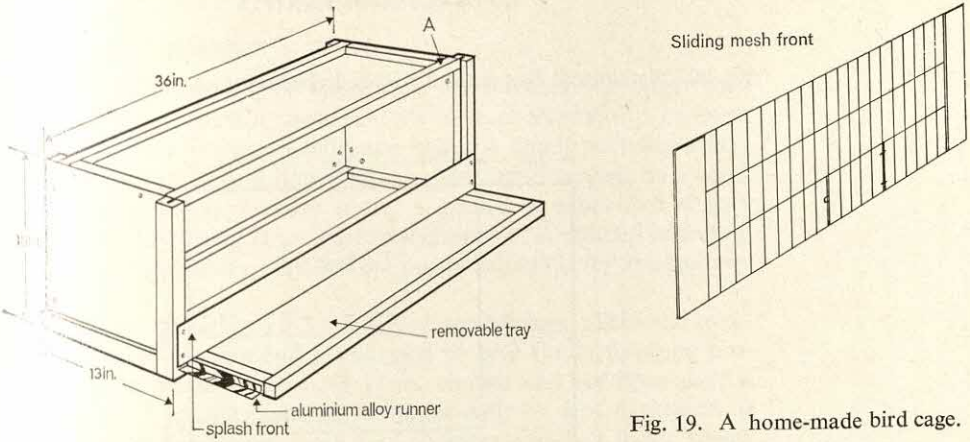


Fig. 19. A home-made bird cage.

Assembly

If the diagram of the bird cage, figure 19, is compared with the general purpose cage described in chapter 1, it can be seen that the two cages, although different in size, are very similar, except that the base of the general purpose cage corresponds to the top of the bird cage. In other words, the general purpose cage is turned upside down to become a bird cage. Therefore, in assembling the bird cage the sequence of operations is the same as for the general purpose cage. Reference should be made to page 41 for the details. In addition the following points should be noted. The wooden piece marked 'A' in figure 19 is fixed to the top flush with the front edge. This allows the mesh front to be slid into place from above. The splash front is a length of hardboard 5 in. wide which is screwed to the front of the cage.

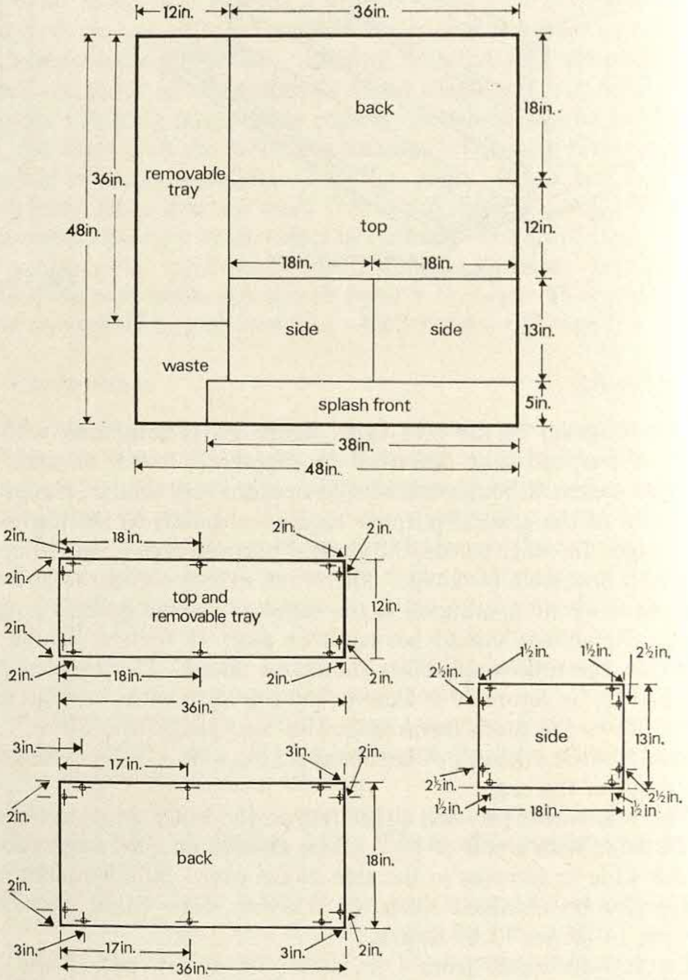
The removable tray can either rest on the bench beneath the cage or be fitted with a pair of $\frac{1}{2}$ x $\frac{1}{2}$ x $\frac{1}{8}$ in. aluminium alloy angle runners which slide in grooves in the side of the cage. Suitable aluminium angle can be obtained from K. Whiston, New Mills, Stockport, costing 1s 1d per 13 in. length.

Perches are made from $\frac{1}{4}$ in. and $\frac{3}{8}$ in. dowel rods. Food pots and water pots are fixed to the front of the cage.

The wire mesh front can be made to slide into grooves at the front of the cage as described on page 90. Alternatively it may be screwed to the front of the cage.

The cage should be coated with polyurethane varnish to seal porous surfaces.

Fig. 20. Marking-out diagram and drilling diagrams for a home-made bird cage.



Note All the holes are drilled $\frac{1}{4}$ in. from the edge of the sheet material, using a 5/32 in. diameter drill

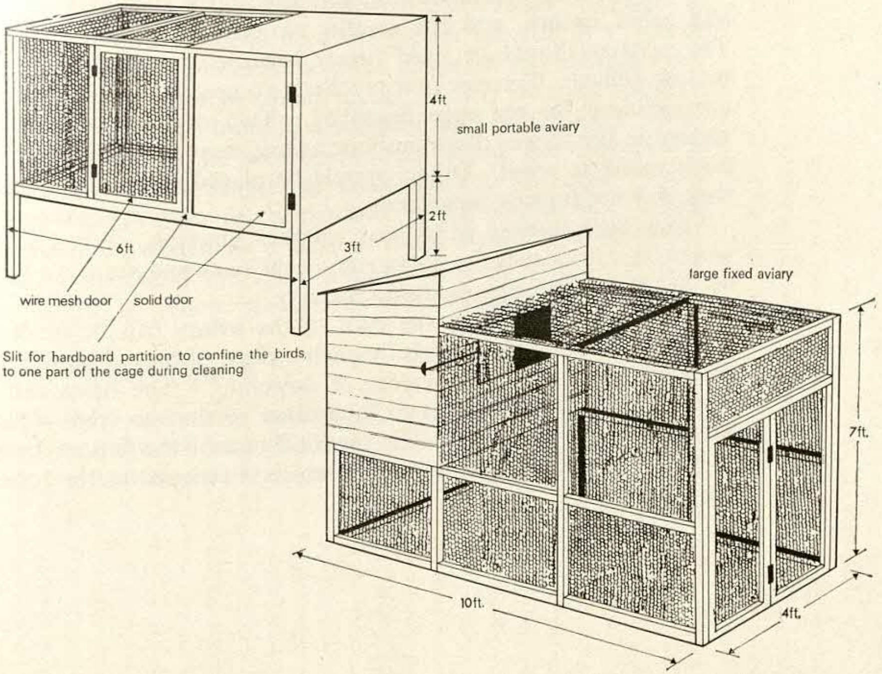
HOME-MADE AVIARIES

It is unlikely there will be space in a classroom for a larger cage than that described, but some schools have overcome this problem by building aviaries in an entrance hall. A small portable aviary of the type illustrated in figure 21 is a great improvement on a cage, in that the birds have more room, a greater number and variety can be kept, and there is an increased chance of successful breeding. In addition, this aviary may be kept out of doors during the summer months.

The size suggested is 6 x 3 x 4 ft high on 2 ft legs. Thus the overall height is 6 ft. One end is enclosed to give the birds some protection. The framework is 1 x 1½ in. timber and the open part is covered with ½ in. wire netting, or better still, 1 x ½ in. Gridweld or Twilweld. Welded wire mesh looks neater and has fewer snags. The floor is a sheet of laconite or hardboard (sealed with varnish) on a wood frame. Two doors give access to all parts of the cage for cleaning, and, if necessary, a hardboard partition can be introduced through a slit in the side of the cage to confine the birds to the covered part.

The other type of enclosure illustrated in figure 21 is a permanent outdoor aviary. This consists of two portions: an enclosed shelter where the birds roost and take cover during inclement weather, and a flight. The overall dimensions are 10 x 4 x 7 ft high, but the size can be adjusted to suit individual requirements. An aviary of this size can comfortably house about twenty non-breeding adults or a

Fig. 21. A small portable aviary and a large fixed aviary with flight and shelter.


4ft
small portable aviary
2ft
6ft
3ft
wire mesh door
solid door
Slit for hardboard partition to confine the birds, to one part of the cage during cleaning
large fixed aviary
7ft.
10ft.
4ft.

smaller number of breeding pairs, say not more than four pairs, plus a few extra cocks. It is an advantage to have an aviary more than 6 ft high so that adults can walk about inside when necessary, without stooping.

The shelter is enclosed, except for a hole about 1 ft square through which the birds pass to and from the flight. The opening is closed at night by a sliding door operated from outside the aviary. The shelter has windows on two sides so that it is well lit inside. The glass of these windows is covered on the inside with wire mesh fixed to removable wooden frames. This prevents the birds from dashing themselves against the glass. The shelter is no more than 4 ft high so that if a bird falls to the floor it can easily regain its perch. The back of the shelter is hinged to facilitate cleaning. It is useful to have a small electric tubular heater inside the shelter on cold nights. This should be covered with perforated zinc so the birds cannot burn themselves. The floor of the flight could be grass, sand, or concrete.

EQUIPMENT FOR CAGES AND AVIARIES

Perches

Some breeders use bark-covered twigs for the reason that they offer the bird a choice of diameters and perching positions. These are difficult to clean and should be replaced at intervals. A 'good' perch is one round which the bird can close its claws; $\frac{3}{8}$ in. and $\frac{1}{2}$ in. dowelling are suitable for the smaller cage birds such as Bengalese and zebra finches, and the smaller varieties of canary (border). The perches should be fixed firmly because loose perches make mating difficult. Three or four perches, two near the top of the cage, are sufficient for the cage described. Two or three perches are needed in the shelter of an outdoor aviary, near the roof where the birds prefer to roost. Others should be placed in the flight where they will not impede movement.

Thick bark-covered twigs have another function. When a bird walks on a thick twig the claws rub on the bark and are worn down so that claw-clipping is seldom necessary.

A perch to hang from the roof of the aviary can be made by boring holes at 6 in. intervals through a piece of broom handle and inserting horizontal cross-pieces of dowelling. The holes can be arranged at different angles to each other so that no cross-piece is directly beneath another. The sawn-off end of the broom handle is inserted in a flat piece of wood, which is screwed to the roof.

Food pots, hoppers, and water containers

Food and water containers should be placed in conspicuous positions, where the birds can see them. They should not be obscured by foliage. An outdoor aviary should have food and water both inside the shelter and out in the flight. Containers must not be placed below perches lest the food be fouled by droppings.

Open pots and dishes are cheap and easy to clean, but soon become fouled. They need more frequent attention than hoppers. Seed-eating birds crack open the seeds and leave the husk behind, and it is necessary to blow off the husks daily from an open dish.

Hoppers contain several days' supply of seed which trickles down into a trough from which the birds feed. Some hoppers incorporate perches with a sliding tray beneath. Droppings and husks usually fall into the tray and there is little contamination of the food. Hoppers with glass fronted containers are best as it is possible to see at a glance when they need refilling.

Mice are attracted by birdseed and the food containers should be placed out of their reach.

It is very convenient if the containers can be removed from outside the cage, or without entering an aviary. In smaller cages the food and water containers are best fixed on the outside of the cage to leave the maximum flight space within the cage.

Nesting boxes

Open-top nesting boxes are suitable for canaries and have the advantage that the whole of the rearing and feeding procedure is visible. Other birds seem to need the greater security of a closed-top nesting box with a hole in the side. Bengalese and zebra finches will usually build nests in round wicker baskets with an entrance hole. These should be hung in a secluded part of the cage. Budgerigar nesting boxes are sometimes fixed outside the cage over a suitable hole. This arrangement saves space in the cage. There should be a perch close to the entrance to the nesting box. Small cracks and holes which could harbour mites should be filled with a proprietary filler and the wood should be given a coat of clear varnish to seal it. These precautions make cleaning easier.

Notes on selected species

Although there are many species of foreign finch which can be reared in captivity, we have produced a short list (pages 96-7) from which a beginner might choose with the certainty that all are well

A selected list of foreign finches suitable for the beginner

Common name	Latin name	Country of origin	Approximate cost	Colour and sex differences	Notes on breeding and management
Bengalese finch (see plate 3)	*Munia striata* (a hybrid)	S.E. Asia	12s 6d to 17s 6d	No plumage differences. Colour generally brown above and paler below with white on the crown, nape of the neck, and flanks. The cock sings.	Builds an untidy domed nest in an open-sided box. Both cock and hen incubate the eggs. They make good foster parents.
Cordon bleu (see plate 2)	*Uraeginthus bengalus* (a waxbill)	Africa	18s 6d	Cocks are brown above, blue below, with red cheek patches. Hens are paler and lack cheek patches.	Very hardy once acclimatized. Sometimes build nests in bunches of twigs or in open-sided nesting boxes.
Fire finch	*Lagonosticta senegala*	Africa	10s upwards	Male is pinkish crimson, browner on back and tail. Tiny white spots on side of breast. Beak crimson. Female is medium to dark brown, with fewer spots. Beak paler.	Breed readily.

Table continued on next page

A.P.

Table continued

G.

Green singing finch	*Serinus mozambicus*	Africa	10s upwards	Female has a necklace of small grey spots across the throat.	Cock has a very fine song, similar to a canary's.
Silverbill (see figure 22)	*Euodice cantans*	Africa and India	10s	No sex differences. Brown above, fawn below, and a lead-coloured tail.	Breed freely in an open-sided box. Readily interbreed with other species.
Avadavat (Strawberry finch) (Tiger finch)	*Amandava amandava*	India and China	10s upwards	Little sex difference during winter. Breeding plumage of male bright red, spotted with white. Beak red. Hen plain yellowish grey, spotted white, red beak.	Male sings sweetly.
Zebra finch (see plate 1)	*Taeniopygia castanotis*	Australia	25s upwards	Cocks have orange cheek patches, and chestnut flanks spotted with white. Both sexes have a barred tail. Cock has a pretty little song.	Breed freely in open-sided box or basket. Place nesting material in the nesting box, so that the female does not build several nests in a 'sandwich'.

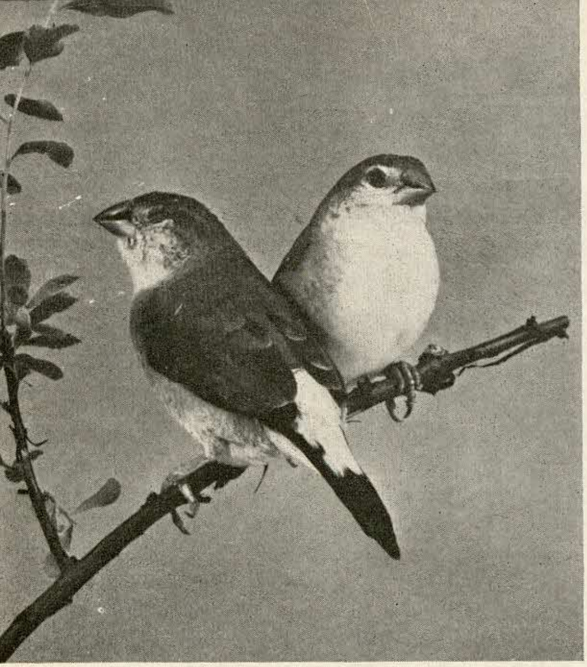


Fig. 22. This pair of silverbills (*Euodice cantans*) had been bought only one week previously, yet allowed the owner to approach them closely enough to take this photograph. Photo H. Lacey.

known for their adaptability and ease of management. References to other species will be found in many of the books listed in the bibliography.

A note on chick-rearing

The approximate temperature requirements of chicks are

Week:	1	2	3	4	5
Temp. °C	32-5	29-32	27-9	24-7	21-4

Any type of heater will do. An electric light bulb is satisfactory. By the eighth week the chicks no longer require extra heat.

The simplest arrangement for rearing the chicks is a cardboard box with top and bottom removed. Newspaper is spread under the box and a little sawdust placed on this. Chicks run in the sawdust. Remove newspaper and sawdust daily. A slightly more refined arrangement is to have a wire mesh frame between newspaper and box. Chicks run on the wire mesh. Sawdust is unnecessary.

Heat is supplied by a lamp suspended from the lid of the box, which can be Claritex or Perspex. Wattage of bulb determines temperature. Take temperature readings approximately 2 inches above floor of box. Do not be too fussy about temperature; aim to keep the chicks warm and out of draughts.

Provide food (chick mash from local shops) and water in shallow, heavy pots or trays which are difficult to overturn. Your local agricultural merchant may be able to show you the devices used on farms for food and drink for larger numbers of chicks.

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Chapter 3

Amphibia and reptiles

Introduction

BECAUSE OUR living British amphibia and reptiles are small, insignificant creatures, it is easy to forget that they are related to the gigantic dinosaurs which dominated these islands some 150 million years ago. The amphibia were the first backboned animals to leave water and colonize dry land. As far as we can tell from fossils this happened some 350-400 million years ago. The conquest of land by the amphibia is a remarkable achievement. It seems likely that certain kinds of aquatic scaly fish were ancestors of the amphibia. These were already partly suited to life out of water; they had lungs, limb-like fins, and a limited ability to wriggle about on mud. Fossil remains suggest that some of these creatures may have lived in rather small freshwater pools which dried out in the summer. Here the ability to crawl or wriggle might enable the animal to move from pool to pool.

There are even a few living species of fish found in Australia, Africa, and South America which have this habit. These are the lung fish. As their name suggests, they, too, have that most important feature necessary to survival out of water—a kind of lung. These fish live in waters which dry up for several months at a time. They survive in muddy holes by breathing atmospheric air.

The earliest amphibian fossils have been found in the rocks of the Devonian period when perhaps the climatic conditions were semi-arid and a heavy rainy season alternated with long periods of drought. Under these conditions, even a relatively crude form of lung was an advantage.

GENERAL FEATURES

Amphibia and reptiles are usually described as cold-blooded animals. This means that they have no mechanism for controlling their body temperature, which always stays close to that of their surroundings. The skin of frogs and other amphibia is moist and, under warm conditions, the evaporation of water from the skin has a cooling effect so that the body temperature is usually less than that of the air. This is true even under cold conditions if the air is dry. Within limits, amphibia and reptiles are more active during warm weather and less so in cold, although the pattern of behaviour varies with the species. The chemical changes such as digestion are affected by temperature changes and proceed more slowly under cold conditions. Prolonged exposure to low temperatures induces a state of coma or hibernation (see page 112).

At irregular intervals a reptile or amphibian sheds the outermost layer of skin. The frequency of moulting depends on external conditions such as the quantity of food available, but the onset of the process is stimulated by the release of hormones into the bloodstream. Newts, snakes, and slow-worms shed the skin whole, while in frogs, toads, and lizards it comes off in fragments.

Features of amphibia

The class amphibia, which includes frogs, toads, newts, and salamanders, consists of animals which, when out of water, tend to live in damp, cool places where there is less chance of an excessive and dangerous loss of water from the body by evaporation. The amphibian skin may be smooth or warty but it lacks the waterproof scales characteristic of reptiles. The skin is richly supplied with blood and is like an extra lung since oxygen passes into the bloodstream after diffusing in through the skin. Carbon dioxide passes through the skin from the blood to the exterior. The skin is only effective as a respiratory organ while it is damp because the oxygen and carbon dioxide must be in solution before they can pass through the skin cells. During the winter months many frogs remain inactive at the bottom of ponds and they obtain sufficient oxygen from the pond water through skin respiration alone. When an amphibian is out of water it may still use the skin for respiration provided it is damp, because oxygen from the air can go into solution in the thin film of water on the skin surface. The lungs are brought into use to supply the greater quantities of oxygen needed when the amphibian is active.

All British amphibia breed in water. Newts, for example, which spend the winter hibernating on land, move into ponds in spring. The similar migrations of frogs and toads take place chiefly at night during February and March. How the amphibia find the breeding ponds is an interesting problem. Newts do not seem to have a good sense of direction and most of their movement on land seems to be aimless wandering. However, they do show some tendency to walk downhill which might be more likely to lead them to water. The migration of toads is more dramatic. Adults emerge from hibernation and move towards selected ponds within the space of a few days, often surmounting major obstacles to reach the breeding site. This movement occurs mainly at night and might be given direction by the scent of oils given off by water plants. Frogs are not so particular but do show some preference for shallow pools, particularly those with an inflow and outflow of water. It might be that the croaking of male frogs and toads (the females do not croak), which arrive early in the breeding pools, guides latecomers, but toads, in particular, have feeble voices.

Both frogs and toads pair off soon after entering the water, sometimes even before. The male clambers on to the back of the female and grasps her with his forelimbs. The black, horny pads on the male's hands may help him to get a better grip. They are well developed during the breeding season. As the female lays her eggs the male sheds sperm over them. This external fertilization could only take place in water as the sperm need a fluid medium in which to swim to the ova. This is one reason why the British amphibia return to water for breeding. When salamanders (from other parts of the world) copulate, the male fertilizes the female internally so they have no need for water at this stage. Salamanders often do mate on land. But all female amphibia, whether fertilized externally or internally, lay their eggs in water. Unlike those of reptiles, amphibians' eggs are not enclosed in a shell and they are so susceptible to dehydration that they could not develop if exposed to air. It is characteristic of amphibia that the young stages hatching from the eggs are adapted to an aquatic life. These are the familiar tadpoles.

Features of reptiles

The reptiles are better adapted to life on land than the amphibia. Lizards and other reptiles seek out warm, sunny places and may spend hours basking in the heat of the sun's rays. Unlike the amphibia they are not restricted to damp places but are to be found

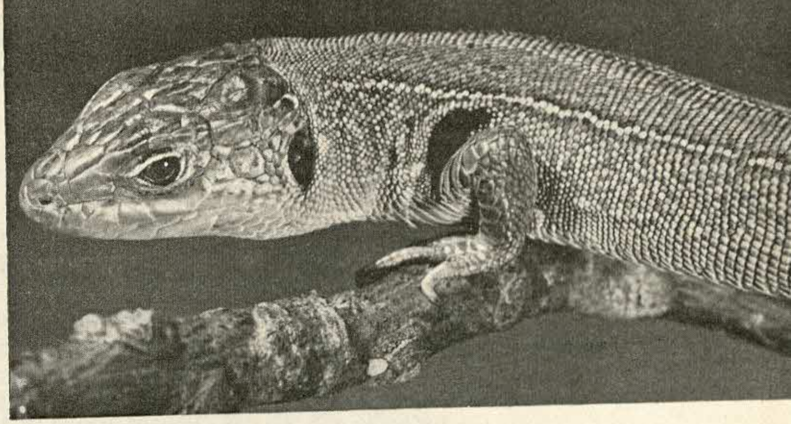

Fig. 23. A green lizard in close-up to show the scaly skin.

on heaths and sand dunes and other areas where the atmosphere is dry. A reptile's skin is dry to the touch, being covered with tough, waterproof scales which retard water loss from the body. It is not used in respiration and the lungs assume a more important role than in the amphibia. Some of the details of the green lizard's exterior can be clearly seen in figure 23.

In their reproductive habits, too, the reptiles are well suited to terrestrial conditions. Fertilization is internal, and in most species the eggs, protected by a soft fibrous shell, are subsequently buried in the soil, or simply deposited on the ground.

Two of the British lizards, the common lizard and the slow-worm, are exceptional since the young reach an advanced stage of development before birth. The young liberate themselves from their membranes as they are born, as figure 24 shows, hence the 'common' lizard's alternative description is appropriately 'viviparous'. There is no tadpole stage in the life cycle of reptiles, whose young resemble the adults in appearance and habits.

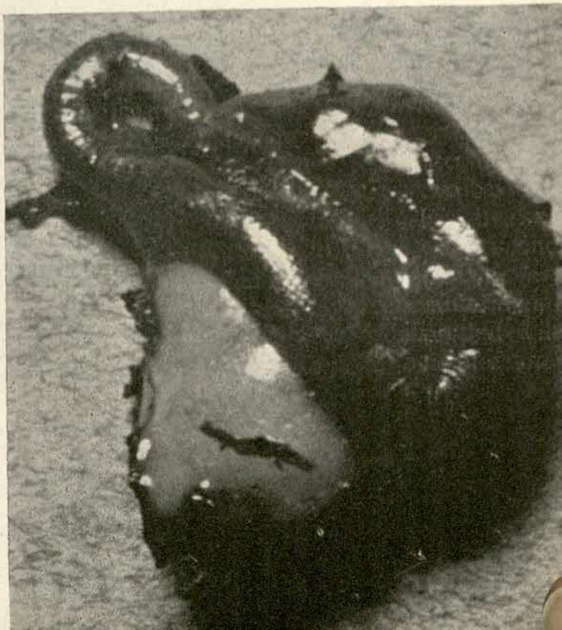

Fig. 24. A newly-born viviparous lizard wriggling free from the embryonic membranes. This tiny specimen is small enough to place on a sixpence.

ORIGIN OF BRITISH SPECIES

In comparison with the rest of Europe, Britain has a meagre number of species and Ireland has hardly any. In Britain there are fourteen species of amphibian and reptile (see below). Of these, four have a local distribution (edible frog, marsh frog, sand lizard, and smooth snake). Ireland has the smooth newt and viviparous lizard, plus two very local species, the natterjack toad and the common frog. The explanation for this scarcity of species lies in the islands' climatic history.

During the last Ice Age the whole of Ireland, Scotland, and the north of England was covered by ice. Conditions in the south of England were very little warmer and it is believed that most if not all amphibia and reptiles died out. Recolonization began some 12,000 years ago, when conditions became warmer, by way of the land bridges which at that time linked Britain with the rest of Europe. But as the sea level gradually rose with the melting of the ice and snow, some 5,000 years ago, the land bridges were submerged so that this route for recolonization became closed. Ireland had become separated from England and Wales even earlier, thus accounting for the very small variety of species there. Since that time several introductions have been made, successfully in the case of marsh frogs and edible frogs in England, and of common frogs in Ireland, but unsuccessfully in the case of green lizards and wall lizards which have not survived in Britain except in the warmer Channel Islands, where they were already common.

The following are the British species:

Amphibia	Warty newt	*Triturus cristatus*
	Smooth newt	*Triturus vulgaris vulgaris*
	Palmate newt	*Triturus helveticus*
	Common toad	*Bufo bufo bufo*
	Natterjack	*Bufo calamita*
	Common frog	*Rana temporaria temporaria*
	Edible frog	*Rana esculenta*
	Marsh frog	*Rana ridibunda ridibunda*
Reptiles	Slow-worm	*Anguis fragilis*
	Sand lizard	*Lacerta agilis agilis*
	Viviparous lizard	*Lacerta vivipara*
	Grass snake	*Natrix natrix natrix*
	Smooth snake	*Coronella austriaca*
	Adder	*Vipera berus berus*

Sources of supply

COLLECTING

Frogs and toads are most vulnerable in early spring when they enter water to breed. At this time they show little inclination to hide or escape and many hundreds fall victim to the catapults and air rifles wielded by adventure-seeking boys. British snakes and lizards do not expose themselves in this way and are usually alert to any danger, slipping off into the undergrowth at the slightest disturbance. Tadpoles are easily come by and those few collected will make little difference to the survival of the species since there is, in any case, a high infant mortality. We advise against collecting the adults of British amphibia and reptiles except to study for a short time and then release them.

PURCHASING

Apart from one or two exceptions, dealers have not found it feasible to breed amphibia and reptiles for sale and most of the specimens offered are collected on the Continent, where there are a greater variety and abundance of species. Nevertheless our responsibility for conservation should extend across the Channel. The least we can do is to buy these animals in small numbers and only when we have proper facilities to keep them in good health. The tragic story of the common tortoise is a salutary reminder of the worst consequences of exploitation of a reptile species. Since 1953 an export limit of 100 tons per year has been enforced in Morocco on the firms which export the common tortoise. Nevertheless the tortoise population is falling appreciably. There are about 3,000 tortoises per ton and the annual total arriving in this country has been calculated as approximately a quarter of a million. It is believed that about one per cent of these survive their first year here. This is a dreadful situation, a product of various forms of mishandling due to ignorance of the principles of how to take care of tortoises. We can do something positive to improve matters by educating ourselves and the children we teach, so that in future, those who buy a tortoise will know what this entails.

Advice as to reliable sources of amphibia and reptiles can be obtained from the Universities Federation for Animal Welfare, 7a Lamb's Conduit Passage, London WC1.

DEALING WITH NEW ARRIVALS

Unless the box has been kept in a very warm place, most reptiles will be lethargic after travelling. This is an advantage since it makes them easier to handle. They should be transferred to their permanent home as soon as possible, and under warm conditions they should soon become active. Appropriate food, usually live insects, should be dropped where the reptile can see it. Drinking water should be available. The smaller species of reptile should start to feed within two or three days unless they happen to be shedding the skin. In this event the animal might not feed for a week or so. Snakes will not feed during the period of eye clotting which precedes moulting.

Amphibia require different conditions because they are animals from cooler, moister places (see page 115). One should aim to provide them with appropriate conditions as quickly as possible, but what these conditions are will depend on the species and the time of year. Newts, for example, should be placed in water if received during the breeding season (spring) and in a vivarium containing damp peat at other times of the year. (See 'Notes on selected species of amphibia and reptiles', page 116.)

SPECIES OF AMPHIBIA AND REPTILE FOR THE BEGINNER TO KEEP

Frogs, toads, newts, salamanders, snakes, lizards, tortoises, terrapins, and even small alligators have been kept in the classroom. Apart from our fourteen native species of amphibia and reptiles, a bewildering variety of these creatures is available from dealers. Most primary school teachers have to cope with frogs or toads brought to school by children, for the life history of either is a popular subject, but it is not widely realized that many other amphibia and some reptiles are easily tamed and make most interesting pets. They show tremendous variety in their life cycles, feeding habits, and behaviour, and much of this can be observed in the classroom.

Of the amphibia, the common toad is very easy to keep and soon becomes tame. Salamanders are also quite easy to manage. The two best reptiles for the beginner are the slow-worm and the green lizard. The green lizard is large enough to be fairly robust and feeds well in captivity. The common tortoise, despite the comments on page 105, is easy to manage provided there is space for it to be kept out of doors in the summer, and indoors in spring and autumn, and properly hibernated in winter if this is desired (page 112). (See also further notes on tortoises on pages 124 and 125.

Management in captivity

GENERAL HYGIENE

It is rare (but not unknown) for amphibia and reptiles to carry diseases which are transmissible to humans. Nevertheless there is much to be said for adopting a similar routine to that advised in the case of mammals, namely that no one should handle an amphibian or reptile with dirty hands, and all should wash their hands after handling or before having a meal.

HANDLING

The secret of successful taming is frequent, gentle handling. The keeper must have regard for the habits of the species, since one cannot expect very lively, active animals to settle down immediately in the hand. Some information on habits is given in the section dealing with individual species: more can be learnt through careful observation. If the animal is a fast moving species (e.g. the wall lizard) it can be very difficult to catch and it should only be handled when it is necessary to transfer it to another cage. All species are easier to handle under cool conditions because their movements are then sluggish. A lizard or slow-worm should never be picked up by the tail since, if at all frightened, it is liable to shed this organ, and although another will regenerate in time, it is never as fine as the original. These animals can be picked up by gripping the body between thumb and forefinger firmly but without undue squeezing. The animals may struggle but if then released onto the palm of the free hand will usually settle down. At first keep this hand within the vivarium so that if the animal escapes it will drop back into the cage. This method of handling works well with the viviparous lizard and the slow-worm, and these are the easiest lizards for beginners to handle. Even freshly caught, wild viviparous lizards often settle down in the palm of the hand with no sign of fear. Salamanders are slow-moving and therefore easy to handle. Toads, shy at first, are readily tamed through frequent handling. Frogs, especially adults, are shy, nervous creatures, and although some individuals become tame after a few weeks in captivity, others remain wild and it is kindest to release these. Sometimes, grass snakes, when first handled, emit an offensive-smelling substance. They soon overcome their nervousness when handled regularly.

ACTIVITY AND SPACE REQUIREMENTS

It is important to recognize that there is a relationship between the animal's characteristic activity and the minimum size of cage required, and a few hints will be sufficient to indicate what is necessary. The cages of jumping animals such as tree frogs, need to be tall in relation to their width. For climbing animals such as some lizards, you will make better use of space if you provide stout twigs. Habitual burrowers like slow-worms should have a greater proportion of floor space and an adequate depth of peat or sand. Requirements for water also differ. The bigger animals require larger bathing places and, although a small saucer is suitable for viviparous lizards, green lizards need a pie dish at least six inches in diameter. Those who specialize in keeping one kind of animal can produce specially designed cages, but for most purposes the cage described on page 114 is adequate. One of its attractive features is that it may be used in one of two positions, in the first giving a floor measuring 18 x 12 in. with a height of 9 in., and in the second giving a floor space of 18 x 9 in. and a height of 12 in.

COMPATIBILITY

Generally speaking, small and large reptiles, whether of the same species or not, should be housed in separate cages.

If large and small reptiles are housed in the same cage the smaller individuals are likely to come off worse in any fights and in competition for food. Therefore the general rule is to keep together individuals of similar size which are equally matched. Snakes should be housed singly because many species eat smaller, weaker amphibia and reptiles including, in some cases, other snakes.

Unless the vivarium is very large it is not usual to house amphibia and reptiles together because it is difficult to establish the rather different conditions preferred by the two groups. Amphibia tend to need shady, humid conditions, whereas reptiles thrive in warm, well lit, dry vivariums.

HEAT AND LIGHT REQUIREMENTS FOR INDOOR VIVARIUMS

(See figure 25)

The British reptiles and those European species commonly sold by dealers are hardy animals which thrive under temperate conditions. A daytime temperature of 15-24°C is most suitable but fluctuations on either side of this cause no harm, especially if tiles or pieces of plant pot are provided beneath which the animals can shelter. It is

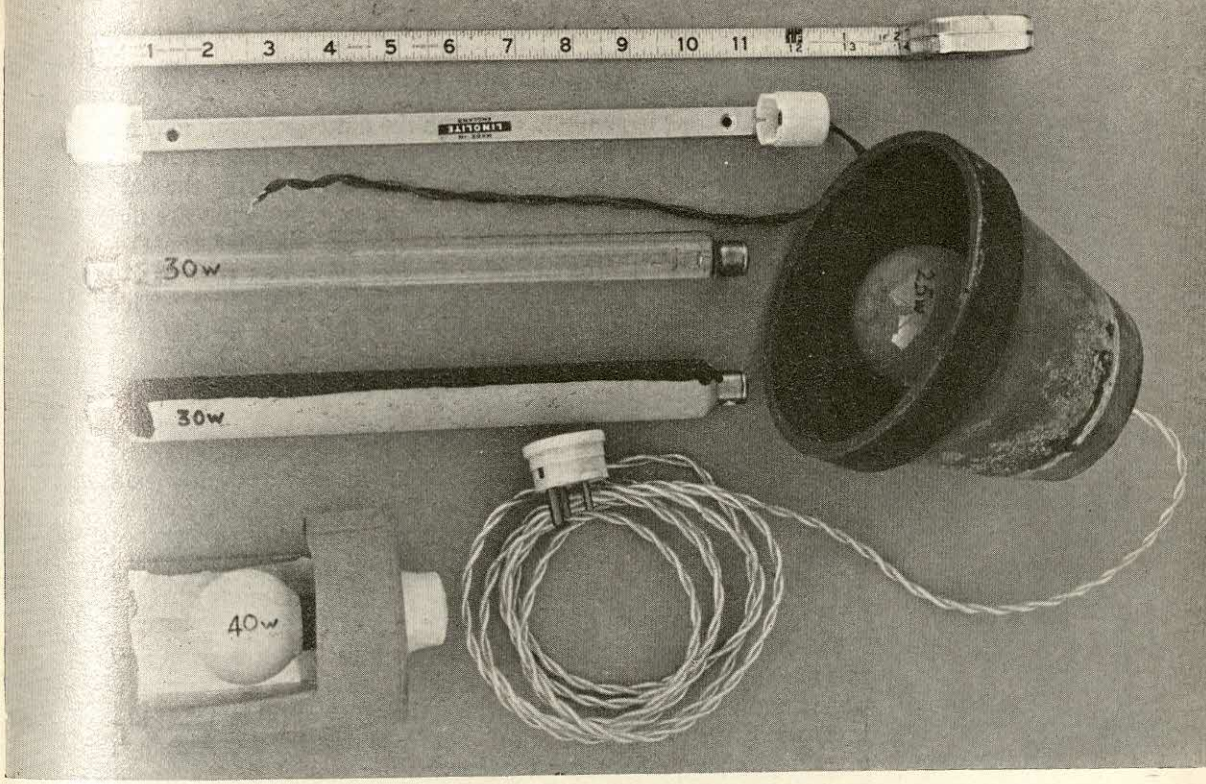

Fig. 25. Heating and lighting equipment for vivariums.

convenient to provide heat and light with a 25 W bulb or 30 W strip light. Both these are warm but not hot to the touch, and even if the most active animals should touch the lamp, they will not be burnt. Many reptiles, especially pregnant females incubating eggs or young, spend a considerable amount of time basking either in sunlight or beneath artificial light and stones should be suitably placed beneath the lamp. Sunlight is beneficial to reptiles because it contains ultra-violet rays which promote vitamin D formation. In the wild state, reptiles have to cope with quite rapid changes in temperature, so in captivity, the lamps can be switched off at night. In the context of the classroom, night means from 4 p.m. to 9 a.m. However, extremes of heat and cold must be avoided, and the animals should not be exposed to the full effects of the sun for long periods, nor should they be in a position liable to frost in winter. A minimum night temperature of 13°C, occasionally falling to 10°C, will do no harm to the reptiles described in this chapter.

British and other European amphibia are equally hardy animals and can be kept at room temperatures up to about 20°C. They do not generally bask in sunlight, although the natterjack toad may do so. Since they spend much of the day in hiding, suitable cover is essential. As they become tame, they will emerge during the day, especially if fed at regular times. Artificial heat and light are not necessary when keeping amphibia during the summer months. Heat without light can be provided during the colder part of the year by an electric lamp beneath an upturned flower pot. This device helps to keep up the temperature of the cage, for instance when the central heating system of the room is switched off.

FOOD

All the British species as well as many European amphibia and reptiles are carnivorous, and the majority are insectivorous, live food being seized in the jaws, or flicked into the mouth with the tongue, and swallowed whole. Snakes generally feed on other vertebrates, including reptiles and amphibia as well as small mammals and birds. Tortoises are herbivorous and terrapins eat small amounts of plant food as well as animal life.

The food given to amphibia and reptiles must be alive, or at any rate moving, since these animals hunt chiefly by sight and detect prey when it moves. A feeding trough with smooth sides to retain the food is especially useful if the animals do not feed immediately. Although many amphibia and reptiles can survive for long periods without food, it is a mistake to use this as an excuse for irregular feeding, since underfed animals will deteriorate in condition. Feeding on alternate days is advisable for the insect eaters during the summer, but no harm will be done if the animals are left without food over the weekend, provided they have had extra on Friday. One cannot generalize about the quantities of food needed, since much depends on the temperature and the size and health of the animal.

It is best to give captive amphibia and reptiles a varied diet. Mealworms and flies can be reared in class and are suitable as a staple diet for the insect eating species. The mealworm is the young stage of a beetle which infests stored grain and cereal products. Both larvae and adults feed on cereals and can be reared fairly simply (but see page 195). The chief drawback is the slow rate of growth of the larvae. At room temperature the life cycle may take 6 months. Mealworms produce very little smell and can be cultured indoors. They are available from dealers. Maggots, the larvae of houseflies and blowflies, grow more rapidly, but their cultures are often smelly and are best kept out of doors. Details of a simple culture technique are given on page 198. Fully grown maggots can often be purchased from fishing tackle shops. If they are kept in a warm room they will soon pupate. The pupae can be placed in a vivarium and the flies will be eaten when they emerge.

Earthworms and slugs are sometimes readily available. We have found piles of half rotten grass cuttings good sources of a small reddish coloured worm which is eaten by green lizards, slow-worms, and salamanders. A moth trap (see page 175) can be an invaluable source of all kinds of insect food.

WATER

Clean drinking water is essential and can be provided in a shallow vessel. Stones or pieces of tile can be arranged around the edge of the vessel to give easy access. Amphibia must have facilities for bathing and reptiles like to have them too. The drinking vessel serves both purposes if it is wide and shallow, at least six inches across and one to two inches deep. Shallow baking tins, pie dishes, or plastic plant pot saucers are all suitable, and, as mentioned on page 116, so are sinks in outdoor enclosures.

CARE AND CLEANING

A very simple routine is sufficient to keep amphibia and reptiles in good condition and their quarters clean and odourless. In normal circumstances the vivarium can be given a thorough cleaning once a year and overhauled at the same time, autumn being most convenient for this operation.

Amphibia produce copious quantities of very dilute urine and it is necessary to change their drinking water regularly as they sometimes urinate into the water. They also void the undigested remains of earlier meals in the form of pellet-like faeces. These should be removed regularly although their presence may not seem objectionable on a peat floor. With reptiles, urine and faeces are combined as whitish droppings, similar to bird droppings. These too, should be removed when dry, although they are not obviously troublesome. Cleanliness is essential to amphibia and reptiles, as it is to all other animals, if they are to remain healthy, and vital to the larger species.

By urinating in this way, reptiles lose little water. This is another of the things which fit them so well for terrestrial life.

Insects occasionally fall into the water vessel and drown, and this is another reason for changing the water regularly. Apart from this the live food poses no problems, since most spiders, insects, and worms live for some time in the vivarium if not immediately eaten. Amphibia and reptiles cast their skins at intervals and the pieces of sloughed-off skin may be removed.

AILMENTS

The commonest sign of ill-health is a persistent refusal to feed, although this should not be confused with the decline in appetite before hibernation or in cool conditions. When it occurs, isolate the animal from its fellows, if possible, and consult the relevant books recommended in the bibliography. If this does not produce a diagnosis, take the animal to a veterinary surgeon. Most ailments can be avoided by securing healthy animals in the first place. Sometimes one finds small blood-sucking mites on a lizard's skin, particularly in the 'armpits'. They can be removed on a small paint brush dipped in liquid paraffin, but they seem to cause irritation rather than harm.

HIBERNATION

This state of torpor is brought on by low temperatures rather than shortage of food and it is easy to maintain captive animals in an active state throughout the year if the night-time temperature of their surroundings does not fall below about 8°C. Day-time temperatures would have to be about 13-15·5°C. However, it is held that in some amphibia and reptiles, a period of hibernation is essential if full breeding condition is to develop. It seems that the eggs or sperms only develop properly when the animal hibernates. It is sometimes convenient to allow captive animals to hibernate, since there may be a shortage of insect food during the winter. It is also a useful opportunity to overhaul and repair vivariums. Some mortality may be expected during hibernation, whereas, kept warm and properly fed, the majority of amphibia and reptiles live for many years.

All amphibia and reptiles, with the exception of adult frogs, are known to hibernate on land, burrowing into heaps of leaves, etc., or underground, although they do not do this invariably. One colony of warty newts, for instance, is known to spend the winter each year in an ornamental pool at Blenheim Palace. In captivity, suitable hibernation quarters can be provided by a tea chest, half-filled with dry leaves, peat moss, straw, or crumpled paper. The animals should be placed in the box during early October unless the nights are warm. They should be covered and the box filled with more leaves, etc., and a cover of perforated zinc nailed on to keep out rats and mice. A dry, unheated, but frostproof shed, cellar, or garage can contain the box undisturbed until spring. A temperature of 1·5-7°C is most suitable for British species, while those from the Continent are best kept at 4·5-7°C.

If the animals are housed in an outdoor enclosure, suitable provision should be made in this for hibernation. Straw or dry leaves placed in a cave constructed from stones will give some protection from the worst of the weather to newts, toads, or lizards. Frogs hibernate in damper places and a pile of wet leaves, similarly placed, will be more suitable.

Different species have their individual times of emergence from hibernation, and further details should be sought in reference books. The beginning of February is not too early to expect the emergence of some amphibia, and a warm spell of weather in March is likely to arouse hibernating reptiles. The animals should be examined at intervals during mild weather in early spring, with as little disturbance as possible, and removed from the hibernation box when they begin to stir. Subsequent treatment depends on the species but it is sensible to avoid rapid changes in temperature. As the animal's tissues warm up it will begin to move about. It may help to immerse it partly in tepid water. A drink of tepid water should certainly be available. After a few days, a little food may be taken. Adult toads and frogs breed immediately after hibernation and do not feed until after that.

Young amphibia and reptiles are less hardy and, in captivity, should be kept warm and fed through the winter.

BREEDING, AND REARING THE YOUNG

Detailed information about breeding habits will be found in the works of reference listed in the bibliography. There is little one can do to induce reproduction of reptiles apart from keeping sexed pairs of animals together. Distinguishing between the sexes can be difficult but many develop characteristic differences during the breeding season. Adult females obtained during the spring are sometimes pregnant and later produce eggs or young. Lizard, snake, or tortoise eggs can be incubated in a warm airing cupboard. Young reptiles and amphibia should be kept separately from the adults, as they are likely to be eaten.

Eggs of amphibia should be kept in clean water. Pond or rain water is best, but tap water that has been allowed to stand for 24 hours before use to allow its harmful chlorine content to escape is also satisfactory. The tadpole larvae of amphibia are not difficult to rear. Frog and toad tadpoles should be given plant food, ideally the slimy green algae common in some ponds (*Spirogyra*). Failing this, any small-leaved water plant, or even lettuce, will do. When they become carnivorous, live foods such as water fleas (page 143) or white worms (page 145) should be given in small quantities. Strips of raw meat can be tried, suspended in the water, to see if the tadpoles will nibble them, but to avoid fouling they ought to be removed after an hour. Newt tadpoles are carnivorous from the time they are born. Water fleas should be their staple food when young, and, later, white worms and small earthworms are suitable.

Housing amphibia and reptiles

CAGES

Good quality vivariums are expensive. A cheaper but equally suitable home-made cage is illustrated in figure 26. This is a modified version of the general purpose cage described in chapter 1, 'Mammals'.

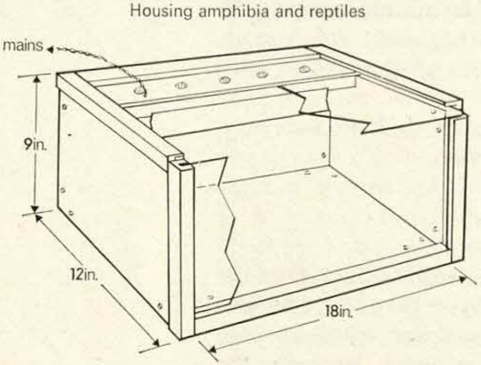

Fig. 26. A general purpose cage set up as a vivarium.

Materials

1 general purpose cage as described on page 34 *et seq.*
1 glass front: $18\frac{7}{8}$ x $8\frac{1}{8}$ in.
1 glass top: $18\frac{7}{8}$ x 9 in.
Planed deal: 18 x $\frac{7}{8}$ in. sq.
Formica: $18\frac{7}{8}$ x $2\frac{1}{2}$ in.
Perforated zinc: 18 x 2 in.
Tinplate: 16 x 3 in.
Strip-lampholder
284 mm strip light, 30W or 60W
6 ft flex
plug
} for heat and light unit

CONSTRUCTION OF HEAT AND LIGHT UNIT

This unit slides into the grooves at the top of the cage. Five holes, about 1 in. in diam. are cut in the Formica strip. Perforated zinc is fixed to the lower surface of the Formica with Evo-Stik. An 18 in. wood support is screwed or glued to the perforated zinc. The strip-lampholder and reflector are screwed to this. A hole is drilled through the wood support to take the flex from the lampholder.

SETTING UP AN INDOOR VIVARIUM FOR REPTILES

In setting up a vivarium the aim is to provide the captive animals with conditions that approximate to those of their natural environment. Within the framework of the animal's needs there is great scope for artistry and ingenuity in establishing a vivarium which is attractive to look at and easy to maintain.

The floor of the cage should be covered with dry sand or gravel to a depth of from one to two inches. Plants, though not essential, can be grown in the vivarium. These should be planted in shallow plant pots or seed pans containing potting compost. A shallow container suitable for dwarf or trailing plants is easily concealed with rocks and stones. The burrowing activities of some reptiles may disturb plants unless they are grown in these containers. Plants must be watered, of course, but although the sand will absorb some of the surplus, do water them sparingly, since dry conditions seem to suit most reptiles kept in captivity. Taking into account these various factors, the plants most likely to thrive are succulents and rock garden plants in the drier, sunnier places, and ferns and house plants in the shadier spots. Some useful hints on growing plants indoors and lists of suitable species, can be found in chapter 6, page 211.

A few large stones or pieces of tile should be placed in one corner to create hiding places for the reptiles. A shallow vessel containing clean water should be embedded in the sand because all reptiles drink regularly. Occasionally we have come across the misconception that they can go for long periods without water.

SETTING UP AN INDOOR VIVARIUM FOR AMPHIBIA

Three to four inches of damp peat should be placed on the floor of the cage. This is preferable to soil, being cleaner and less likely to contain fungus spores. The vivarium should be set up in a shaded part of the room, and, if plants are grown in it, shade-loving species such as ferns are best. The aim is to provide a humid atmosphere and moderate temperatures. Hiding places and water should be provided as in the case of the reptiles. During the breeding season frogs, toads, and newts should be kept in aquariums.

OUTDOOR ENCLOSURES

European amphibia and reptiles are hardy animals which thrive in suitable open-air enclosures where conditions can be made to simulate those in the wild. However, continuous observation is more difficult; the animals are less likely to become tame and, although the natural food supplies within the enclosure will augment or even replace hand-feeding, one cannot keep a check on the food consumption of individuals.

On the other hand, for shy, nervous animals, an outdoor enclosure is best. It may take the form of a pit or stockade but should have smooth, vertical sides, preferably with an overhanging top, which can be made of glass, smooth brick or glazed tiles, or asbestos. Shallow sinks (e.g. a kitchen sink) make suitable bathing and drinking places if they are so arranged that the animals can enter and leave the water easily. The outdoor enclosure must be so placed as to give the inmates a choice of sun or shade, and there should be shelters for the animals to creep into during bad weather. [illegible]ght (1956 and 1962) gives constructional details for both temporary and permanent outdoor accommodation for amphibia and reptiles.

Notes on selected species of amphibia and reptiles

SMOOTH NEWT (*Triturus vulgaris*)

Distribution

This is the commonest newt in England and the only species found in Ireland. It is present in Wales and Scotland but is not so common there as the palmate newt, especially in hilly areas.

Habits

From about July onwards the smooth newt follows a terrestrial existence, lying up during the day in shady places often near ponds, and emerging to feed at dusk on all kinds of terrestrial invertebrates. It goes into hibernation on land in October.

Reproduction

Smooth newts generally start to breed in their fourth year when they are three to three and a half inches long, including the tail. They enter the water in March after emerging from hibernation and mate towards the end of the month and in April. The adult male has a fine crest along the back from neck to tail and engages in much courtship display, lashing his tail in front of the female before releasing a packet of spermatozoa on the bed of the pond.

If the female is ready she picks up the spermatozoa in her cloaca (vent), where they wriggle free and fertilize the eggs within the female. A few days later the female deposits the eggs singly, usually wrapping each in a leaf of a water plant. Both display and egg laying can be seen if newts are kept in an aquarium during the spring. Newt tadpoles hatch after three or four weeks, have external gills at first, and are carnivorous. Limbs gradually develop and the adult features are assumed within about four months.

Management in captivity

Specimens obtained during the spring should be housed in an aquarium containing at least 6 in. depth of water to encourage breeding. The tank should have a lid in case the newts try to escape. During this aquatic phase in the life cycle newts can be fed on water shrimps and aquatic insects. They may also accept *Enchytrae* and chopped earthworms (see pages 145-6).

After the breeding season (about July) the adult newts leave the water. They will climb on to rafts of wood or cork floating in the tank. Some people release newts at this stage, but if they are to be kept they should be moved to a vivarium of the usual amphibian type (see pages 114-5).

EUROPEAN SALAMANDER (*Salamandra salamandra*)

Distribution

This species (figure 27) is found in hilly districts in many parts of Europe. There are two varieties, a spotted form commoner in south eastern Europe, and a striped form found in France and the western regions of Germany.

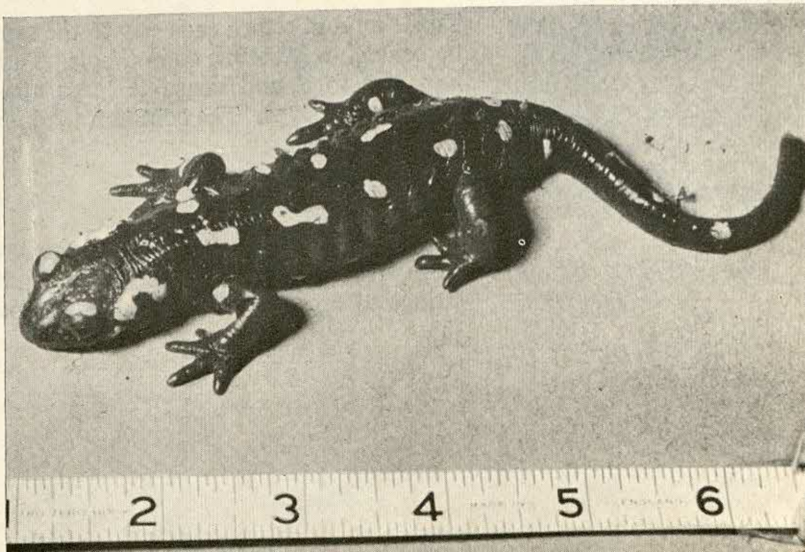

Fig. 27. European salamander (*Salamandra salamandra*).

Habits

The European salamander is more active in the evening and at night, though at all times it is lethargic, and therefore easily handled. It lives in damp places, usually near a stream, and feeds on worms and insects. Salamanders are not difficult to keep in captivity and they are long lived. The breeding behaviour of the adults is similar to that of the related newts, the chief difference being that mating occurs on land. The young, which are subsequently deposited in shallow water by the female, are enclosed in a membrane at birth, but they soon escape from this and start to feed on water fleas, etc., almost immediately. Young salamanders live in water being tadpole-like with a tail and external gills, though walking limbs are present at birth.

Management in captivity

The vivarium to house salamanders should have a damp peat or moss floor. The water supply should be in a large shallow dish at least 6 in. square, for the salamander periodically wets its skin by immersion. Small earthworms, slugs, woodlice, and mealworms are favourite foods in captivity. Small pieces of meat might be offered as a change of diet but these must be wiggled to simulate the movements of live prey.

COMMON TOAD (*Bufo bufo*)

Distribution

The common toad is widely distributed throughout England, Wales, and Scotland, but is not found in Ireland.

Habits

Toads tend to return each day to the same hiding place which may be beneath a flat stone or in a hole. They emerge in the evening to hunt for food and consume large quantities of insects, worms, spiders, and slugs. The common toad is easily tamed and will feed from the hand.

Reproduction

Toads pair up and enter the ponds somewhat later in the year than frogs, usually at the end of March and beginning of April. The strings of eggs are laid in the deeper parts of ponds and if frogs frequent the same pool there is little mixing of either adults, or, subsequently, tadpoles. Toad tadpoles are blackish in colour and the tip of the tail is rounded. Frog tadpoles of the same age are larger, with speckled, olive coloured bodies and tails with pointed tips. The colour distinctions become more obvious when the tadpoles are large.

Management in captivity

Damp conditions in the vivarium suit toads very well. They have enormous appetites and seldom refuse food such as earthworms, maggots, mealworms, and flies. Toads are among the more intelligent amphibia and make good pets.

NATTERJACK TOAD (*Bufo calamita*)

Distribution

This attractive little toad (figure 28) has a scattered distribution, being found in sandy districts, particularly on the coast in several parts of England and in County Kerry.

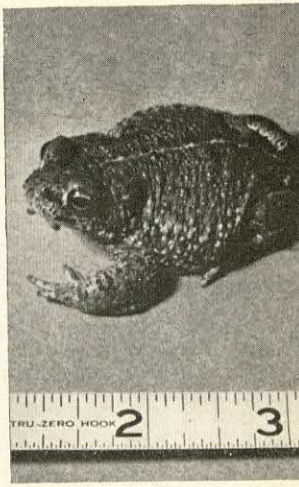

Fig. 28. Natterjack toad (*Bufo calamita*).

Habits

It burrows underground during the day and emerges in the evening, though sometimes coming out to bask in the sun. Natterjacks have short limbs and crawl rather than hop. They eat all kinds of worms, insects, and spiders.

Reproduction

Mating occurs during the spring and strings of eggs are laid in shallow water. The tadpoles are similar in feeding habits and general development to those of other toads and frogs.

Management in captivity

Sand and peat mixed make a good burrowing medium for the natterjack. Otherwise management is the same as for the common toad.

GREEN TREE FROG (*Hyla arborea*)

Distribution

There are many species of tree frog and, in spite of the name, they are toads, not frogs. *H. arborea* comes from central and southern Europe.

Habits

Tree frogs are superb climbers, for by means of the adhesive discs on the tip of each digit, they can scale smooth, vertical surfaces with ease. During the summer months they spend most of their [illegible] in vegetation, but earlier in the year they are to be found in [illegible] near ponds where the eggs are laid. Tree frogs are chiefly nocturnal animals but there is some evidence of activity being related to hunger rather than external conditions. Flies are their chief diet.

Reproduction

The breeding behaviour of the green tree frog is similar to that of our British frogs and toads, eggs being laid in stagnant water and fertilized there by the male. Other species of tree frog have more unusual breeding habits. The female Jamaican tree frog lays her eggs in water caught between the leaves of Bromeliads, tropical plants related to the pineapple. Another species, *Hyla rosenbergii*, builds a basin of mud on the margin of a pool in which the female lays her eggs. Under these conditions where there is a limited food supply, the tadpoles tend to be cannibalistic.

Management in captivity

Vivariums for tree frogs need to be tall in relation to their width and length to give the animals scope for climbing and jumping. A fully grown adult measures no more than 2 inches in length so the cage need not be large. A simple vivarium can be made from a plastic cylinder 12 in. long and 5 inches in diameter (see page 171). A sweet jar is quite suitable. Tree frogs are easy to keep provided a supply of live flies can be maintained (page 198). They are fascinating to watch as they climb up smooth vertical surfaces or jump several times their own length to catch a fly.

COMMON FROG (*Rana temporaria*)

Distribution

Though decreasing in numbers, it is common in all parts of Britain and is also found in Ireland, chiefly in coastal areas. (Plate 4.)

Habits

Frogs hunt for food in the evenings and are usually to be found in damp places. They move on land by crawling and jumping, so adults, if kept for any length of time, should be housed in a large vivarium, preferably an outdoor enclosure. Failing this, the vivarium should have a height of two feet to allow unrestricted movement. Although nervous animals, they can be tamed, but less readily than toads. Their diet includes a wide range of insects, slugs, and spiders.

Reproduction

The breeding behaviour of the adults and the development of the frog tadpole are too well known to warrant detailed treatment here. The processes are no less fascinating for being commonly observed. Common frogs become sexually mature in their third year when they are about two inches or so in length. Mating and egg-laying occur in February and early March, shallow water being chosen, though the reason for this is not known.

Management in captivity

Adult frogs are less well suited to captivity than most amphibia. Tadpoles, on the other hand, thrive if properly looked after. The best food for young tadpoles is the slimy green 'scum' found in many stagnant pools during the spring. This is usually the tangled filaments of a simple form of plant life known as green algae (see also pages 133 and 282). In appearance it resembles wet cotton wool. As they grow, the tadpoles will browse off larger water plants such as water cress and Canadian pondweed. Eventually they will start to eat small animals such as water fleas (page 143). It is most convenient to keep small aquatic animals of this kind in the same jar or tank as the tadpoles so that live animal food is always available. When tadpoles are being reared in tap water that contains no other forms of animal life it is necessary to give the tadpoles small pieces of meat to nibble. This is best done by hanging small pieces of fresh liver in the water on a piece of string. Meat should not be left in the water overnight because it quickly decays and this will foul the water. The change to a carnivorous diet is gradual and is usually completed by the time the tadpoles are two months old.

VIVIPAROUS LIZARD (*Lacerta vivipara*)

Distribution

This lizard is common in most parts of Britain and in Ireland, and is the species most likely to be found by children.

Habits

Viviparous lizards are active animals, coming out of hiding to bask in the sun. They are easily tamed and can be taken out of the cage on the palm of the hand. Their diet includes small earthworms, spiders, slugs, and small insects, including mealworms (page 195).

Reproduction

Adults breed at two years of age when they are 4½ to 5 in. long, including the tail. They mate in April or May and the bronze-brown young are born in July. The baby lizards are from 1½ to 2 in. long and thrive on tiny insects such as aphids. They must be housed separately from the adults; a plastic lunch box fitted with a gauze cover is a suitable cage for the young.

Management in captivity

Although they are easy to handle, viviparous lizards are not the best lizards for the beginner to keep since they are rather fragile, easily shed their tails, and do not usually live for more than a year in captivity. It is best to keep them for short periods during the summer and release them during the summer holidays.

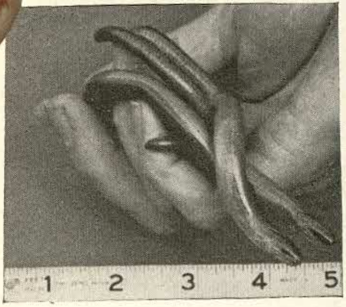

Fig. 29. Male and female slow-worms (*Anguis fragilis*).

SLOW-WORM (*Anguis fragilis*)

Distribution

Although present in most parts of Britain the slow-worm (figure 29) is commonest in the south and west. It is absent from Ireland.

Habits

Much of the day is spent in hiding beneath flat stones or buried in the ground. Pregnant females incubate their developing embryos by basking in the sun during the summer months. Slow-worm movements are deliberate and they are therefore easy to handle, soon becoming tame. Their diet is similar to that of the viviparous lizard and they can be kept in the same cage.

Reproduction

Breeding adults commonly measure 13 to 16 in., including the tail, attaining this length after four or five years. Mating occurs in the late spring and the young are usually born towards the end of August or in September, being about 3 in. long and gold and black in colour. The young should be separated from the parents and fed on tiny insects.

Management in captivity

Slow-worms go about the business of catching food with great deliberation and, in captivity, they find it easier to catch slugs and other slow moving creatures than fast moving flies, etc. Earthworms, slugs, and mealworms are the best staple foods.

GREEN LIZARD (*Lacerta viridis*)

Distribution

This species (figure 30) is not a native of Britain but it is common in many parts of Europe and in the Channel Islands, where it has been introduced. It is often available from dealers.

Habits and management in captivity

It is a large, bright green lizard, adults measuring over 12 in., including the tail. A pair can be comfortably housed in a vivarium measuring 24 x 12 x 12 in., but they are active animals and stout twigs should be provided for them to climb on. Extra care should be taken to guard against escapes until the animals are tame. They are capable of jumping a foot in the air and could conceivably leap out of the vivarium if the cover was left off for long periods. They eat worms, spiders, and all kinds of insect, both large and small. It is wise not to keep them in the same cage as the much smaller viviparous lizard. Green lizards are very suitable for the beginner to keep, being robust and relatively hardy.

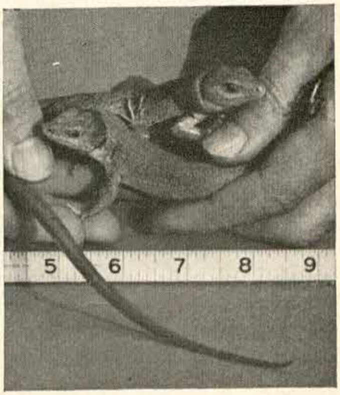

Fig. 30. Male and female green lizards (*Lacerta viridis*). The female is in front of the male.

Reproduction

Adults mate in the late spring, at which time there is much rivalry and fighting, both within and between the sexes, although little damage is usually done. Eggs are buried in the ground in midsummer and hatch in about a month. They should be incubated in a warm place.

GRASS SNAKE (*Natrix natrix*)

Distribution

This species appears to be absent from Ireland and Scotland but present in all parts of England and Wales.

Habits

Grass snakes bask in the sun or, on dull days, take shelter beneath stones and in other places. They will feed at any time, if hungry, on frogs, lizards, newts, small mammals, and young birds. The prey is swallowed whole and the left and right sides of both upper and lower jaws can move independently so that the mouth has an enormous gape. The sight of a snake swallowing an animal is not pleasant and this is a factor to take into account when deciding whether to keep this species in captivity. Supplying food can also prove difficult. On the other hand, the grass snake is soon tamed and makes an interesting pet.

Reproduction

They breed when three to four years old, at which age the male is about 20 in. in length and the female slightly longer. Mating occurs in April and May and eggs are laid in June and July among warm, decaying vegetable matter. The young hatch after two months, are just over 6 in. long at birth, and are a darker colour than the parents.

SPUR-THIGHED TORTOISE (*Testudo graeca*)

Distribution

The specimens imported into Britain mostly come from North Africa, from Morocco, but the species is also common in southern Spain, and Sicily.

Habits and management in captivity

As is well known, the tortoise is herbivorous and needs a wide variety of fresh plant food such as lettuce, cabbage, and other garden vegetables, soft fruits, and the leaves of dandelions or plantains. Tortoises immerse their heads when drinking, so a dish should be provided into which the animal can lower its head. A piece of cuttle-fish bone, obtainable from pet shops, is a convenient source of calcium needed for the shell. Tortoises prefer sunny conditions and can be kept in an outdoor enclosure during the summer months. Unlike the terrapin, the tortoise requires dry conditions for hibernation.

Reproduction

The male tortoise has a concave under-surface and a long tail. The female has a flat under-surface and a short tail. Eggs are sometimes laid in captivity and, if found, should be incubated at a temperature of 27-29·5°C, under which conditions they should hatch within three months. At lower temperatures incubation takes longer. Newly hatched tortoises should be placed in a shallow dish of tepid water where they may take a drink. They will not feed at first but should be offered finely shredded lettuce after a few days. When they are a few weeks old, small amounts of finely powdered cuttle-fish bone or chalk should be sprinkled on the food to help development of the shell.

EUROPEAN TERRAPIN (*Emys orbicularis*)

Distribution

This species is common in many parts of southern Europe. Attempts to introduce it into England have not been successful but small specimens are commonly available from dealers. It is wise to choose the largest active terrapin available since small specimens under 2 in. are delicate.

Habits and management in captivity

Terrapins are quite good swimmers and this species spends a great proportion of the day swimming and hunting for food such as water insects. It also basks in the sun on suitably placed rocks. In captivity their requirements are very easily supplied. A large dish, half filled with water, having an island of stones in the centre, is all that is required. A cover is not necessary unless the dish is very shallow. Sunlight and shade should be available, weather permitting! Small individuals can be fed three times a week on *Enchytrae* (see page 145) or tiny pieces of worm. Specimens three inches long or more need to be fed no more than twice a week, and will usually take small, whole earthworms, insects, snails, and some plant food. Terrapins feed in the water and, because they tend to soil the tank, it is convenient to feed them in a separate dish, leaving them with the food for a couple of hours, and then return them to their living quarters. Terrapins can be hibernated in a biscuit tin containing damp leaves, the top being covered with perforated zinc.

Reproduction

In the wild state eggs can take up to three months to hatch and indeed, in a cold summer may not hatch at all. Therefore all eggs produced in captivity should be incubated under warm conditions. Minute aquatic life such as water fleas (page 143) should be fed to the young.

Sources of information, specimens, and materials

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STATE INSTITUTE OF EDUCATION
Govt. of West Bengal

Materials

Vivariums can be obtained from:

P. K. Dutt & Co., Ltd., Clan Works, Howard Road, Bromley, Kent.

Flatters & Garnett Ltd., Mikrops House, Bradnor Road, Manchester 22.

T. Gerrard & Co., Ltd., 4 Angel House, Pentonville Road, London N1.

Philip Harris Ltd., Ludgate Hill, Birmingham 3.

Specimens

L. Haig & Co., Ltd., Beambrook, Newdigate, Surrey.

South Western Aquarists, 2 Glenburnie Road, Tooting Bec, SW17.

Societies

The British Herpetological Society, c/o The Zoological Society of London, Regent's Park, London NW1.

Aim: to promote the study, care, and conservation of reptiles and amphibians, in particular in Britain and Europe. Regular meetings are held in London and a journal is produced about once a year.

Chapter 4

Freshwater tropical aquariums

Introduction

MOST OF US have, at some time or another, seen an attractive tropical aquarium with brilliantly coloured fishes swimming among luxuriant foliage in crystal-clear water. Perhaps we have assumed that the keeping of exotic looking fishes is an expensive hobby requiring expert knowledge and, while admiring the achievements of others, have been deterred from starting ourselves.

The tropical aquarium is no more difficult to establish and maintain than the cold water aquarium; indeed in one respect it is more likely to be a success since one makes a deliberate attempt to control the temperature and amount of light. The initial cost is greater, but there is some expectation of a financial return through the sale, subsequently, of fish and plants reared in the aquarium. Some dealers are willing to buy fish and plants from amateurs, either for cash, or in exchange for other species.

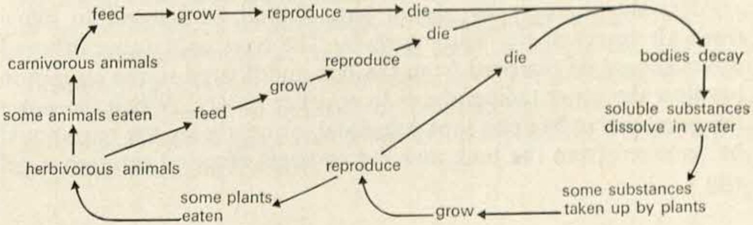
There is a great deal of potential educational value in the keeping of aquariums in school. The children involved may gain first-hand experience of scientific topics such as the relationships between plants and animals, the habits and life cycles of fish, snails, and other animals, the growth and propagation of aquatic plants, the effect of light on plants, the principles involved in the thermostat, the heater, the thermometer, evaporation, condensation, the siphon, etc. In addition, questions about the country of origin of tropical fishes may be a stimulus for geographical studies, and it is virtually certain that the variety of form, colour, and movement in the tropical tank will be a powerful stimulus for creative expression through painting, modelling, or writing.

The tropical species of fish offer a greater variety of life cycle, habit, colour, and shape than their cold water relatives, and many have shorter life cycles, reaching sexual maturity within a few months of birth. The beginner often assumes that the breeding of tropical fish needs great skill only acquired by a long apprenticeship in keeping fish. While this is true of some species, there are others which breed under almost any conditions fit for survival, and, unlike our native species, breed at any time of the year.

In an aquarium one aims to set up a balance between the animal and plant life in such a way that each contributes to the other's welfare. Plants must have light + water + carbon dioxide + mineral salts for healthy growth. (Animals, on the other hand, must have organized organic food such as that obtained by eating plants or other animals.) A well established aquarium, whether tropical or cold water, is a self-contained unit in which the animals and plants support one another to a great extent. Some fish and snails feed on the plants; others are carnivorous and eat smaller fish or minute aquatic animals. Waste released by the animals includes carbon dioxide and nitrogenous matter. Plants use carbon dioxide and various dissolved salts including nitrates. They grow, reproduce, and so produce more plant matter which is eaten by animals, and so on (figure 31). An aquarium containing healthy, growing plants can support more fish than one without.

In practice it is very difficult to make an aquarium completely self-sustaining, and it is necessary to give the fish small amounts of food. Nevertheless, the tropical aquarium, once established, requires less maintenance than the cold water aquarium because the conditions of light intensity and temperature are more carefully controlled at levels close to the optimum for plant growth. Most tropical aquarium fishes grow best at temperatures ranging from 22-24°C, and this is the range usually aimed at in the tank. It is worth noting that water of this temperature does not feel lukewarm to the hand. Some beginners, assuming that the tropical tank should contain 'warm' water, are inclined to doubt the accuracy of the thermometer and 'allow for this' with disastrous results. It is always reassuring to check the water temperature with a second thermometer, but when in doubt, always trust the instrument and do not rely on subjective impressions of temperature.

Fig. 31. Diagram illustrating interdependence of plants and animals.



Sources of supply

PURCHASING TROPICAL FISH

Where the help of an experienced aquarist may be had, there should be no difficulty in obtaining healthy fish. Signs of ill-health include: dorsal fin folded flat along the body instead of being erect; fish which mope on the bottom of the tank instead of swimming around in a lively manner; minute white spots on fins and body (beware of temperatures of over 26°C in the dealers' tanks, as this may mean that the fish are being treated for 'white spot'—see page 148); hump back; signs of wasting and general lack of colour and liveliness.

The beginner is advised to join a local aquarists' society and seek advice from the members. Many are very willing to help and some might even supply schools with their surplus fish.

TRANSPORTING FISH

Two plastic bags, one inside the other for safety, make good containers for carrying fish. They should be supported in a cardboard box or tin which has been lined with an insulating material. Cork chippings, Vermiculite, sawdust, or torn up newspaper, all make good insulating material. The base of the box should be well covered, the double plastic bags containing water and fish should then be placed in the box, after which the sides should be filled with insulating material, and then a cover placed over the top. The bag should be no more than half full of water, leaving a large air space. As the fish use up oxygen in the water more dissolves from that in the air space. The top of the plastic bags should be secured with a rubber band to prevent water spilling out.

DEALING WITH NEW ARRIVALS

On introducing fish to an aquarium there are two important principles to remember. One is the variations in temperature and their effect on the fish, and the other is the possibility of introducing disease-producing organisms.

After the journey the plastic bags should be opened to allow fresh air to reach the water surface. The bags containing fish and water should be removed from the box and floated in the aquarium to allow the water temperatures to equalize slowly. When the water temperatures in bag and tank are equal, or nearly so, the bag should be removed from the tank and the contents emptied through a net held over a sink. The fish are caught in the net and immediately placed in the aquarium. Many fish are excellent jumpers and it is always necessary to cover the mouth of the net with the hand when transferring fish.

Throwing away the water in which the fish have been carried reduces the chances of contamination, in particular, from the minute organism which causes the disease known as 'white spot'. Fish which have been chilled, for example, during transport, are more likely to be affected by this disease (see page 148).

When setting up a tank for the first time the fish might as well be placed in it as soon as they arrive. With an established tank it is sensible to take greater care to prevent the introduction of disease. In this case, newly bought fish should be kept in a separate quarantine tank for two to three weeks before they are allowed into the established tank. Ailing fish will usually reveal their ill-health during the quarantine period.

SPECIES OF FISH AND PLANTS FOR THE BEGINNER

Those who have no experience of keeping tropical fish should start with species that can tolerate a certain amount of inexpert treatment, do not need special food, and breed readily. One group of tropical fishes, namely the 'live bearers', stands out in this respect. They include the well known guppy, the platy, and the red swordtail. We strongly advise the beginner to start with one or more of these species, buying a male and two or three females with the object of breeding to increase the stock. Early success with these fish will give confidence and possibly capital to buy other species. Many aquarists have started in this way, exchanging fish for other species or equipment.

The guppy (plate 5) is a typical live bearer and is the ideal beginner's fish. It is often beautifully marked, it breeds readily, takes a wide variety of foods, and is more tolerant of temperature fluctuations than most fish. The female guppy, like other live bearers, retains fertilized eggs inside her body where they develop, causing a marked distension of her belly. The young hatch from the eggs just before birth and emerge as small, but perfectly formed fish, about a quarter of an inch long. The advantage to the beginner is that these baby fish are large enough to take such food as newly hatched brine shrimps (page 144) and other live foods as well as powdered dry food. It is not necessary to culture the microscopic forms of live food known as *infusoria* (page 142) which are indispensable when breeding many kinds of tropical fish.

The best plants to start with are strongly growing types that thrive in a wide variety of conditions and propagate easily. We recommend *Vallisneria spiralis* (figure 32) and *Hygrophila polysperma* for a first planting. These have contrasting foliage, the former grass-like and the latter with privet-shaped leaves. Both grow quickly in a heated tank. Other species can be added later (see page 157).

Management in captivity

GENERAL HYGIENE

So far as is known, tropical fish do not carry diseases which can be contracted by humans. The aquarist practises good hygiene for the benefit of the fish and plants in his tanks. Sources of infection include newly bought fish, plants, and the water they travel in, pond or river water containing minute forms of life (see page 134), and equipment such as nets used in tanks containing diseased fish. Common sense precautions largely eliminate these hazards.

HANDLING

Fish should be handled as little as possible. They should be moved from one tank to another in a net. Large rectangular nets are more useful than small circular ones (page 156). If it is necessary to hold a fish, the hands should first be wetted.

Plants should never be allowed to dry out. If it is necessary to take them out of the tank, they should be kept in bowls, jars, or Polythene bags. They will come to no harm if kept at room temperature for a few days.

COMPATIBILITY OF FISH

Most of the fish listed on pages 154-5 can be kept together in a communal tank. Beginners are advised to start with those species of fish known as 'live bearers', e.g. guppies and mollies (plates 5 and 6), because they are easy to breed. The great majority of these species can be kept together.

It is wise to avoid having a majority of males of a species, otherwise the females tend to be overworked. (Guppies are an exception; it does not seem to matter with this type of fish.) If there are two males of a species in a tank one usually becomes dominant and may constantly harry the other. When there are larger numbers, a 'peck order' is usually established and the bickering is less severe.

ACTIVITY AND SPACE REQUIREMENTS

Shallow tanks are better than deep aquariums of the same volume because there is a greater surface area for oxygen to diffuse into the water and for carbon dioxide to escape into the atmosphere. Large fish use up more oxygen than small fish; active types more than slow swimmers. Slight overcrowding might produce no obvious ill effects but in the long term, growth, breeding, and general health are all affected adversely. In a tank with an average amount of foliage it is safe to assume that adult guppies need a minimum of about 3 sq in. of air surface per fish. Adult swordtails and platies (plates 7 and 8) need about 8 sq in. per fish. An established tank with a surface area of 288 sq in. (24 x 12 in.) can be expected to support a dozen platies and 50 guppies.

HEAT AND LIGHT REQUIREMENTS

The rivers and streams of America, Asia, and Africa, which are the natural homes of many fish kept in aquariums, do not have constant conditions of temperature and light intensity. There is therefore no reason to suppose that the fish must have constant conditions when kept in captivity. It is necessary to prevent the water from becoming too cold. An average temperature of 24°C suits most fish and they come to no harm if the temperature ranges from 21-26°C, provided the fluctuations in temperature are not rapid. Overnight temperature changes of 3°C or so will do no harm, but one should not suddenly transfer fish to another tank until the water temperatures are the same to a degree or less.

The plants in an aquarium will not thrive unless they receive sufficient light. If too much light falls on the tank, plant growth will be luxuriant, so much so that the small plants called green algae (pages 121 and 282) will develop on the glass sides and obscure the view. In addition the water may be coloured green by millions of these minute green plants. The algae do no harm except to spoil the appearance of the tank. A certain amount of algal growth is inevitable and is easily removed (see page 146), but it can be discouraged by reducing the amount of light falling on the aquarium. Aquariums are best kept away from sunny south facing windows. Most tropical aquarists prefer to keep their aquariums in shady positions and control the amount of light by using electric lamps for up to 10 hours or so each day. Two 40 W lamps provide ample illumination for a 2 x 1 ft tank kept in a shady place. Signs that too little light is reaching the tank are weak looking plants with long straggly leaves and stems.

Some aquarists prefer to paint out three sides of the tank, leaving the front clear for viewing to simulate natural conditions where most light falls on the plants from above. The same effect is eventually obtained by cleaning algae only from the front wall of the tank.

AQUARIUM SITUATION

An ideal situation is in front of a north facing window (see page 133). A 2 x 1 x 1 ft tank weighs about a hundredweight when full of water, so it must be placed on a strong table. The tank should be placed in its final position empty and checked to see that it does not wobble. It must not be moved when full of water since this will possibly crack the glass by setting up strains.

WATER

Fortunately for aquarists most fish and aquatic plants can tolerate soft-hard or acid-alkaline conditions if they are not extreme. Usually tap water is very satisfactory for use in aquariums. Tap water contains a certain amount of dissolved chlorine gas. That is the main reason for 'seasoning' tap water for at least 24 hours before using it in an aquarium. The addition of 3 grains of photographic hypo to a gallon of water will shorten this 'seasoning' process but the writer has never found it necessary to go to this trouble.

In districts where the water is known to be very hard it would be advisable to use rain water. Boiling removes some hardness. The water is allowed to cool and settle and only the top part of the water is used. Owing to concentration by evaporation, hardness increases over a period of months unless some of the water is removed. It is advisable to siphon off about 10 per cent of the water occasionally and to top up with rain water. Distilled water may be used to help reduce hardness in water. Water from pond or stream could be used in aquariums though the problems of transport usually prevent this. Also there is a danger of introducing organisms harmful to the fish, so such water should be boiled and allowed to stand for a day or so before being used.

AQUARIUM FLOOR MEDIUM

The choice of material for use on the aquarium floor is of great importance to the general wellbeing of the occupants. Should the material used be too fine, water will not circulate through it and the plant roots may not get sufficient oxygen and mineral salts. Consequently the plants will not thrive. If the material is too coarse, neaten food may settle where the fish cannot reach it and pollution may set in. Pollution may be recognized in its early stages by the blackening of the gravel underneath the area in which the fish are fed. This condition is most likely to happen when the fish are fed on a diet of dry food, fresh meat, or fish and too much is given at any one feed. More will be said about this under the heading 'Food for tropical aquarium fishes' (page 139).

It might be thought that the plants in an aquarium will only hrive if their roots are in soil or compost. However, truly aquatic lants can absorb some mineral salts from the water and in time, hese are supplemented by salts released from the decaying fish roppings which form a 'mulm' on the bed of the tank. Thus it is not necessary to underlay the gravel with soil—indeed its use may ell cause cloudy water and much trouble. Should it be felt that a spectacular plant such as an Amazon sword plant needs special attention, it is better to plant it in a thumb pot in soil or compost, covering the surface of this with gravel.

Very coarse sand or fine gravel, $\frac{1}{16}$-$\frac{1}{8}$ in. in diameter, is most suitable for the aquarium floor. This must be thoroughly washed in the following manner. Taking a little of the gravel at a time, place it in a bucket under a tap. Turn on the water and as it flows stir the gravel with a stick. Pour off the water and repeat the procedure until, upon allowing the gravel to settle for a few seconds, the water in the bucket becomes clear. There is no need to boil the gravel, as sometimes advocated, unless it is known that unwanted algae spores are present. Gravel which has become black with pollution may easily be cleaned by washing as described above and then placing the gravel thinly on a tray exposed to sunlight. After a few days it will be found that the gravel has assumed its original colour. A natural setting for fish and plants may be obtained by using peat as a floor medium. If this is used, it will need to be soaked in water for several days, otherwise it will float to the surface. Even after this time it may be necessary to anchor the peat down by the use of stones. The peat should be in large lumps.

Rocks which may be used for decorating should be thoroughly washed before being introduced to the tank. Limestone is not good for this purpose as it would tend to make the water hard. Although this condition might well suit the plants, it will not suit the majority of fishes. Sandstones of various kinds make ideal decorative material. The use of highly coloured artificial pebbles as offered in some pet shops is to be deplored. So also is the use of 'sunken ships', 'treasure chests', 'mermaids', and the like. Conditions as natural as possible should be aimed at in the aquarium.

SETTING UP AN AQUARIUM

It is best to check for leaks before setting up the tank permanently. Aquariums which have dried out through lack of use will probably leak owing to shrinkage of cement. Sometimes a newly filled tank will stop leaking after a few days but this does not always happen and we recommend treatment to prevent leaks while the tank is still dry. One simple method is to paint the glass to glass joints inside the tank, which should be clean and dry, with a waterproof varnish such as that used on yachts, generally described as marine varnish. Three coats applied on successive days, or as each coat is dry, should be given. We have not had an opportunity to test polyurethane varnish for this job, but we suspect it might be most suitable.

If the tank is dirty it can be cleaned by gentle rubbing with fine grade steel wool. The dirt is rinsed away with tap water. Unless the tank is very greasy it is best not to use soaps or detergents because they are difficult to wash away completely, and even small amounts can be lethal to fish.

The clean, leak-free tank should then be placed in its permanent position for setting up.

Arrange the gravel on the floor of the aquarium to a depth of 2-3 in. at the rear and sides, sloping to about ¾ in. at the front. This allows any debris to gravitate to the front of the tank where it can be seen and is easily removed. Rocks should then be introduced as desired. About 4 in. depth of water should now be added to the tank, causing as little disturbance as possible to the gravel. One good method is to lay a sheet of paper over the gravel (clean newspaper will do) and place a shallow dish on top. A slow stream of water directed into the dish will spill over onto the paper which breaks up the flow and prevents disturbance of the gravel. The dish can then be removed and the paper will float up and can be removed. Wait for the water to warm up at least to room temperature (it does no harm to introduce the heater and thermostat at this stage, provided they are immersed), before introducing plants. This may be done by hand or by using planting sticks. The latter are essential when introducing plants to a tank full of water. The front, centre area of the tank should be left clear of plants as a swimming space where the fish will be clearly seen. It is generally effective to have plants of the same kind grouped together. A spacing of one inch will usually allow sufficient room for growth of such plants as *Vallisneria*, *Sagittaria*, and *Cabomba*, while *Cryptocoryne* and other broad leaved plants need a wider spacing (see page 137). Rooted

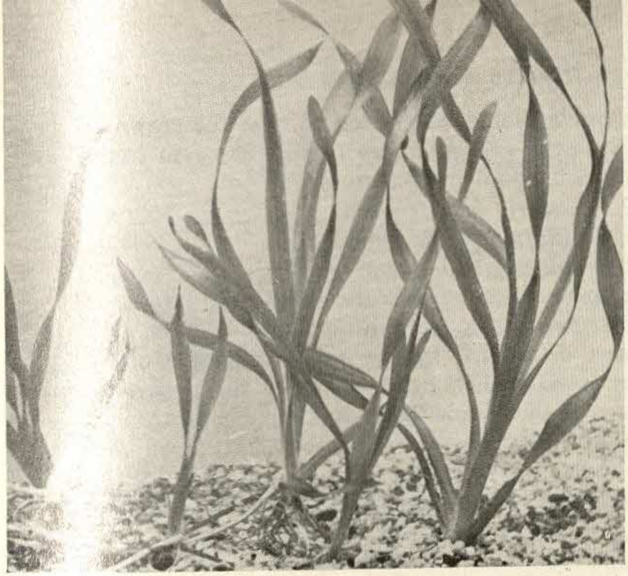


Fig. 32. *Vallisneria spiralis*. Photo, Laurence Perkins.

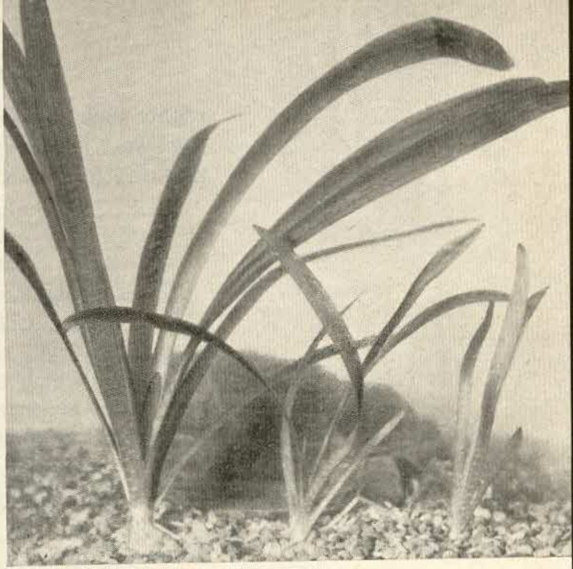


Fig. 33. *Sagittaria latifolia*. Photo, Laurence Perkins.

Fig. 34. *Cabomba caroliniana*. Photo, Laurence Perkins.

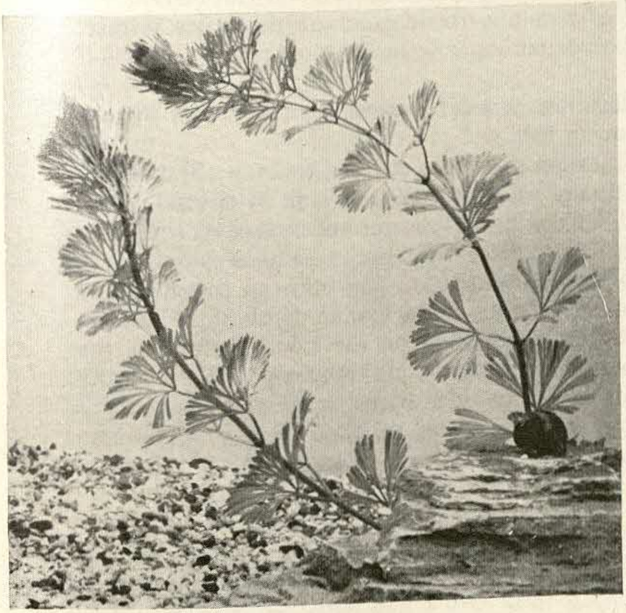
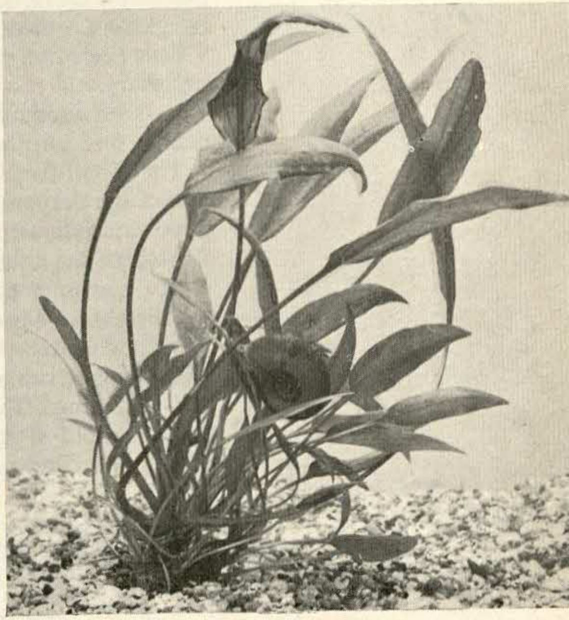


Fig. 35. *Cryptocoryne*. Photo, Laurence Perkins.



plants such as *Vallisneria* should be planted so that the wn of the plant is just above the gravel surface (figure 32). initial planting for a 2 x 1 ft tank might consist of:

12 *Vallisneria spiralis* (*torta*)
6 *Sagittaria latifolia* (figure 33)
6 *Cryptocoryne* (figure 35).

The approximate cost of these at current prices would b 2s. If the aquarium at first appears to be a little underfurnis with plants, this will soon be righted by the natural increa f the *Vallisneria* which sends out runners from which new plan elop.

Page 157 gives notes on these and other plants suitable f pical aquariums. Should there be a need to anchor the plants d until they are sufficiently rooted it is best to use a spiral coil of l rips. Plumbers usually have small pieces of sheet lead from w trips may be cut.

The heater and thermostat should be placed at the re f the tank at opposite ends. The heater should rest on top of t avel, held down, if necessary, by a strip of lead. The temperat ould be checked over a period of several days and the thermosta usted if necessary to give an average daytime temperature of 2

A scum sometimes appears on the water surface of a new a rium due to oil escaping from the aquarium cement. It can be oved by placing a piece of semi-absorbent paper on the wate rface. This is peeled off after a minute or so and the operation rep ated if necessary.

It is advisable to allow at least a week for the plants to take root before introducing fish.

The top of the aquarium should be covered to keep out dust and reduce the evaporation of water. If the tank is lit by electric lamps, these can be housed in a combined reflector and dust cover to fit over the top of the aquarium. Sheets of glass can be used as covers. It is not necessary to leave a ventilation gap between the glass and the metal frame provided there is an inch or so depth of air between glass and water. Water condensing on the under-surface of the glass tends to run between glass and aquarium frame and eventually causes rusting. This can be avoided by using specially made alloy clips to hold slightly smaller pieces of glass clear of the frame (figure 36). These are sold by dealers in tropical fish.

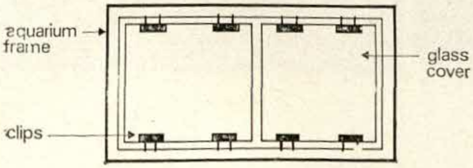


Fig. 36. A glass cover fitted just inside the aquarium frame by means of alloy clips.

TABLE 1 Examples of fish foods

Home-made dry food	Home-made fresh food	Live foods
Dry boiled liver	Kidney	Infusorians
	Beef	Micro-worms
Dried boiled egg yolk	Crabmeat	Water fleas
	Fish	Brine shrimps
	Shellfish	Grindal worms
	Lettuce	White worms
		Tubifex worms
		Earthworms

FOOD FOR TROPICAL AQUARIUM FISHES

The commoner species of aquarium fish are omnivorous, and will accept a wide variety of foods. Commercially prepared dry fish food is a very satisfactory staple diet for fish such as guppies, swordtails, and platies (beginners' fish, see page 131) and is undoubtedly the most convenient for the teacher with a limited amount of time. There are many good prepared dry foods on the market. The writer has found Tetramin flakes (drums from 3s 3d), Hykro flakes (1s), and Exotic flakes (1s) very useful. Dried ants' 'eggs' are of doubtful value. Dusty preparations with many very finely ground particles should be avoided because the fish eat the larger particles and leave the dust which soon fouls the water (see page 147).

Uneaten food falls to the bottom of the tank and, if not removed, decays and may foul the water. To avoid this it is best to feed the fish two or three times a day, giving small quantities only, so that all the food given is consumed within five minutes. Fish should not be given extra amounts of food before the weekend. It is better for them to go without than to have an excess of food lying on the bed of the tank.

The fish will develop a finer condition if they are given a change of diet. Table 1 lists some home-made foods and live foods which are suitable. Prepared foods must be chopped up finely so that the fish can swallow particles whole without choking.

TABLE 2 A summary of features of live foods suitable for tropical fishes

Common name	Zoological name	Maximum size	Type of animal	Source
Infusorians	*Infusoria*	microscopic	protozoa & rotifers	from dealers or established tanks
Micro-worms	*Anguilluda silusia*	·5 mm long	nematode	from dealers
Water fleas	*Daphnia* spp.	2 mm long	crustacean	from dealers and ponds
Brine shrimps	*Artemia salina*	1 mm long (larvae)	crustacean	from dealers as eggs
Grindal worms	*Enchytraeus buchholzii*	5 mm long	annelid	from dealers
White worms	*Enchytraeus albidus*	15 mm long	annelid	from dealers
Mud worms	*Tubifex* spp.	20 mm long	annelid	from dealers and muddy ponds
Earthworms	Several species	15 cm long	annelid	from gardens

Ease of culturing	Culture medium	Optimum temperature	Suitability
easy and quick	on lettuce in water	at 21°C	for newly hatched fry of egg-laying species
easy and fairly prolific	on finely ground oatmeal + yeast (or bread and milk)	at 21°C	for fry of egg layers aged 2 weeks +, and newly hatched live-bearers
difficult to culture continuously	on infusorians or 'green' water	at 18°C	the best general-purpose food
eggs stored dry and hatched when required	salt water or sea water	at 21°C	for young live-bearers rinse in fresh water before adding to the tank
easy and prolific	on soil + baby cereal	at 21°C	good general-purpose food for adults of smaller species
easy and prolific	on soil + bread and milk	at 16°C	good general-purpose food thought to be fattening
difficult to culture in quantity	on mud with small pieces of bread in running water	at 16°C	good general-purpose food
difficult to culture in quantity	on soil with leaf mould	at 16°C	chopped up as a food for adult fishes

The term 'live food' refers to a wide variety of organisms which can be fed to fish. Small organisms such as water fleas will live in the tank for a time and there is little danger of their polluting the water. Certain species of fish (see pages 154-5) must have live food included in their diet. All fish, save a few wholly herbivorous species, benefit from occasional meals of live food. The busy teacher would not wish to attempt the culture of the many types of live food listed in table 1, but we have included notes on each of these to show the range of live foods available. Some are cultured by virtually every aquarist who sells fish. Others can be obtained from specialist dealers. A source of live food cultures is given on page [illegible]. Apart from their value as fish food, live foods and their cultures can be a most interesting study.

Table 2 (pages 140-1) summarizes the main features of the best-known live foods. Further details follow.

Infusorians

The fry of most egg layers are so small that they must be fed on microscopic food until they are capable of eating brine shrimps, sifted *Daphnia*, etc. In most established aquariums numbers of these organisms are present. There are many ways of culturing infusorians. One way is to half fill a beaker with water taken from the aquarium and add it to a piece of lettuce leaf which has been crushed and bruised. Place in a warm place or float the beaker in the aquarium. After a few days, careful observation should reveal clouds of minute creatures suspended in the water. A hand lens is useful in observing their presence. Another method is to boil a handful of hay in water. After cooling pass the water through a fine sieve. Half fill a beaker with the infusion and add a small amount of water taken from an old established aquarium. After a few days a large population of micro-organisms should be present (the culture is kept in a warm place as before). A useful exercise connected with the preparation of these cultures may be undertaken as follows. Prepare the infusion of hay as above. Place beakers containing a quantity of the infusion in various parts of the room. Do not add anything other than the infusion. Record the temperatures of the infusion daily and also inspect for micro-organisms.

When the cultures are ready for use (they will have to be set up about a week before the fish spawn, new cultures being set up on alternate days to ensure a continuous supply for a period of about two weeks), they are best introduced in the following way. Fill a beaker of the culture and place it on top of the aquarium cover.

Fix in position a length of small-bore plastic or rubber tubing with a clamp in position. Fill the tube with water and set it up as if to siphon the infusion from the beaker. As soon as you are certain that the siphon is working, screw down the clamp so that only a drip escapes into the tank. By this method a continuous drip of infusorians is supplied to the tank. Another method is to empty a supply of the culture at intervals. The danger in this method is that there will be competition for the supply of oxygen in the aquarium.

Green water such as old water in flower vases is a very useful food for the newly hatched fry of egg layers.

Micro-worms

A shallow sloping sided porcelain or glazed earthenware dish is suitable for the culture of these worms. The culture medium is prepared in the following manner. A quantity of finely ground oatmeal is boiled up with sufficient water so that, when cooled down, a stiff paste is obtained. Half a teaspoon of dried or fresh yeast is mixed with a little water and stirred into the cooled oatmeal. Now add the worms. A glass cover plate is provided and the dish should be kept in a warm place such as the top of the aquarium cover (21°C). After a few days masses of the minute worms may be observed on the sides of the dish. A camel-hair brush is useful for removing them. When a vertical sided dish is used, it helps to separate the worms from the culture if a clean, thin piece of wood is floated on the surface of the oatmeal. The worms will climb out onto the wood making it easier for them to be removed. These worms are difficult to see at first. A useful way of ensuring that they are present is to add a tiny drop of the culture to a test-tube full of clean water. If the worms are present, they may easily be seen in the test-tube. When a culture is at its peak, if the dish is held so that the surface is against the light, a shimmering mass may be observed.

These worms are useful live food for the young of live bearers, and also for egg layers when they are about two or three weeks old.

Fresh cultures should be set up every two weeks using the old culture for inoculating the new. Cultures of these worms may be obtained from dealers at small cost.

Water fleas (Daphnia)

This is particularly useful live food, for the obtaining of a supply can lead to much interest and investigation on the part of the children. In their search for *Daphnia* they will come across many other things which may arouse their curiosity. *Daphnia* are found in ponds where there is some form of decaying organic matter. The population of any pond will vary from time to time, one day present in vast clouds, another day apparently absent. The best way to collect the crustaceans is to use a plankton net which is swept through the water. They should be placed in a bucket or other wide-mouthed container which has been filled with water from the pond. *Daphnia* are very demanding in their requirement of oxygen. When oxygen is deficient they rise to the surface. If it is intended to keep a supply, the container should have a large surface area.

When feeding *Daphnia* to fish there is a danger of introducing disease organisms into the aquarium. This risk can be minimized by pouring a quantity of the water containing the *Daphnia* through a plankton net, and returning the pond water to the container. Fresh tap water is now passed through the plankton net and the contents are thoroughly washed before being fed to the fish.

Daphnia are most valuable as a food for all fishes. Fish which are being brought into breeding condition benefit from the addition of *Daphnia* to their diet. They appear to have a laxative effect on the fish, so they are useful where the diet consists mainly of dry food. Sifted *Daphnia* are useful for the appropriate stage in the rearing of young fish, i.e. after the infusorian stage in egg layers and for the young of live-bearers soon after birth.

Daphnia may be kept in any container with a large surface area An extremely cheap and useful container suitable for keeping *Daphnia*, and indeed for other purposes, may be made by lining a shallow wooden box with Polythene. Green water should be fed to the *Daphnia*. *Daphnia* feed on minute pond plants and animals such as green algae and protozoa. An infusorian culture is a suitable food for a *Daphnia* culture. Some aquarists have also kept very good cultures of *Daphnia* going by sprinkling a *little* Horlicks on the surface of the culture daily.

For further details see: Galtsoff, P. S., *et al* (1937).

Brine shrimps (Artemia salina)

Brine shrimp eggs are gathered from the edges of salt lakes mainly in the United States. To obtain a hatching of these shrimps, place sea water, or fresh water to which has been added two tablespoons of common salt to a pint, in a container. Add as many eggs as will cover a sixpence and keep the container in a warm place (18-21°C would be suitable). The use of aeration, if available, will lead to better hatches. The brine may be used several times and in any opping up that may be necessary due to evaporation, fresh water may be used.

For feeding to the fish, the shrimps are removed as follows. Pass quantity of the culture through a plankton net or through any et made of fine material. Remove any salt by washing the net nder a running tap before feeding directly to the fish.

Brine shrimp eggs are available from most dealers at 2s 6d per tube.

A combined thermostat and heater (they are both contained in he same tube) can be useful in the culture of brine shrimps in a omparatively small container, when used with aeration. However or general use this apparatus is not recommended.

Grindal worms

These are very small worms and may be kept in a moist soil though they prefer a rather high temperature of about 21°C. It is advisable to pass the soil, peat, or leaf-mould through a fine sieve before use and if the soil is on the heavy side add some sand to the compost. Oxo tins which have held a gross of cubes make ideal containers for this purpose. Puncture the lid with holes for ventilation. Feeding needs care as overfeeding quickly sours the compost and kills the worms. Baby cereal, such as Farex, is suitable for these worms. Half a teaspoonful of the cereal should be mixed with tepid water and spread on the surface of the soil. Small pieces of glass on the surface of the soil are useful as the worms collect on these. Provided these pieces of glass are kept clean, feeding of the fish may take place directly by dipping the glass into the aquarium.

White worms (Enchytrae)

These worms may be kept in boxes in moist spongy soil to which has been added leaf-mould or granulated peat. To set up a culture, place a layer of the soil 1 inch deep on the bottom of the box. Add a thin layer of cold cooked porridge oats. Add a small portion of the starter culture. Cover with an inch of soil. Repeat the process until the box is full. Place a piece of glass over the surface of the soil. This helps to prevent drying out of the soil. Worms will be found on the underside of the glass from which they can be removed with tweezers for feeding to the fish. It will take a little time for the culture to become productive. They should be fed every two or three days. Dry oatmeal or bread (either brown or white) soaked in water, may be placed in holes in the soil and covered over. Once the culture is well established small pieces of soaked bread placed on the surface of the soil will induce the worms to surface when they are required for feeding. As with fish the rule for feeding should be a little and often. Overfeeding sours the soil. Bread soaked in milk is good but there is a danger that souring may take place if too much is given. When surface feeding, old food should be removed before new is given.

The top of the box should be ventilated. When it is seen that the soil is drying, the surface may be sprinkled with tepid water. The cultures do best in the dark at a temperature of not more than 15°C.

Mites will usually be found with these cultures but they do no harm.

When making up the soil for both grindal and white worm cultures, the addition of powdered charcoal will help to keep the cultures sweet.

Tubifex worms

These worms are to be found in nature in the mud of ponds and river estuaries. They can often be obtained from aquarist shops and they are particularly useful to the town dweller who has not got access to ponds, etc., where other forms of live food may be obtained. These worms need to be kept in a container under a continuous flow of fresh water such as a slowly running tap. Worms not immediately eaten by the fish may become established in the floor of the aquarium. This causes no harm and usually the fish will eat these worms in due course.

Earthworms

These, when chopped up finely, make excellent food for all kinds of fish. Though we quite happily feed whole white or grindal worms to fish, the thought of chopping up live garden worms does not appeal to many people. Nevertheless when other fresh food is not obtainable, earthworms, which are usually easy to obtain, make a useful emergency addition to the food supply.

CARE AND CLEANING

As the aquarium becomes established the water will become crystal clear. Sometimes the water turns green. This is due to the growth of the minute plants called green algae (pages 133 and 282) and they may become troublesome inasmuch as they obscure the view. They grow prolifically in strong light and the remedy is to reduce the illumination falling on the tank. Some forms of green algae form a green film on the glass sides of the tank. This can be removed by rubbing with a soft cloth. Fine steel wool will remove any more resistant coatings but should be used gently to avoid scratching the glass. Some aquarists use a razor blade mounted in a holder specially made for the purpose. Small quantities of green algae are beneficial, being eaten by certain species of fish, as well as by snails.

Evaporation will cause a drop in the water level. It is sometimes useful to draw the children's attention to this phenomenon which can be measured and recorded. Topping up the aquarium should be done regularly, say once a week. The use of a clean watering can fitted with a rose causes little disturbance of the water.

Fish droppings fall to the floor of the tank and decay slowly, through the action of bacteria. Dissolved salts which escape from the decayed droppings or mulm are a useful source of minerals for the aquarium plants. Eventually a thick layer of mulm accumulates on the floor of the tank and the excess should be removed, either by siphoning or sediment removers. The latter somewhat resemble the domestic vacuum cleaner and function like it. One type is worked by hand (Windmill hand rejector, price 15s) and another can be fixed to the airline of an aerator pump (Windmill air rejector, 10s). More expensive types, costing about 50s, are worked by batteries.

One should always be on the lookout for signs of pollution. This is usually caused by giving too much food, but an unnoticed dead fish may also be responsible. These are the usual causes of a rapid increase in the amount of organic matter in the water which allows a rapid growth in the populations of bacteria. The water becomes cloudy and deficient in oxygen and the fish will be seen swimming near the water surface, occasionally breaking the surface to gulf air. If this happens, the water must be changed quickly without giving the fish the additional shock of a sudden change of temperature.

BREEDING TROPICAL FISH

In most species of fish the female lays her eggs in the presence of the male who then sheds sperms over them to effect fertilization. It so happens that the easiest tropical fish to breed in captivity have a different method of reproduction. These fish, known as live bearers, include the guppy, the platy, and the swordtails. In them the male copulates with the female and the eggs are fertilized inside her body. She retains the eggs for an indefinite period depending on external conditions, particularly the temperature. The eggs develop and eventually hatch, still inside her egg ducts. When they are born the fish sometimes measure ¼ in. in length, and can soon swim vigorously, as well as being able to eat food such as newly hatched brine shrimps, micro-worms, and powdered dry food. Their relatively large size and robust nature makes the fry of live bearers the easiest of all tropical fish to rear, although adults tend to eat the young.

The table of selected fish lists fish with the egg-laying habit, such as the zebra fish, which scatters eggs on the floor of the aquarium. The adults are likely to eat the eggs. This can be prevented by having a layer of pebbles on the floor of the tank. At least some eggs will fall between crevices out of reach of the parents. The fry of these egg-laying species are very tiny at birth and must be fed with cultures of infusorians (page 142). After two or three weeks they can be given slightly larger food.

We also list species with unusual breeding habits such as the bubble nest builders (e.g. three-spot gourami) and mouth-breeders (e.g. *Haplochromis multicolor*). These are types of fish which have evolved a greater degree of parental care and look after their eggs and young for a time. Although we have excluded details of treatment of these species we mention them in the certainty that some teachers, encouraged by success in breeding live bearers, will be on the lookout for interesting additions to their stocks of fish. Further information will be found in the books listed on pages 157-8.

AILMENTS

The commonest disease of tropical aquarium fishes is an affliction covering the fins and body, known as 'white spot', caused by a tiny protozoan (single celled animal). The cause of white spot is nearly always a sudden fall in the water temperature. This has the double effect of decreasing the resistance of the fish to infection while at the same time increasing the vitality of the parasite. The best treatment is to raise the water temperature to about 30°C for several days and shade the tank. If the fish can be transferred to another tank without plants a chemical treatment can be applied in addition to the heat treatment. This consists of adding methylene blue to the water at a concentration of 2 drops of 5 per cent aqueous solution to the gallon. This should not be added to an established tank since it is usually fatal to plant life. The fish should be kept in the hospital tank until the white spots disappear. This usually takes a week.

There are other diseases which occasionally affect tropical fish, but if the beginner takes care to obtain stock from a reliable source he will usually avoid troubles of this sort. More frequently, the oxygen content of the water is too low, either through overcrowding or from water pollution caused by overfeeding. Attention to these matters is by far the quickest route to successful fish keeping.

Aquariums and other equipment

AQUARIUM DESIGN, SIZE

The depth of an aquarium should not be greater than its width. This is a useful rule of thumb to employ when purchasing a tank. Of course, the same result is gained by half-filling a deep aquarium, but the evaporation of water always leaves an unsightly tide mark across the glass which is not seen if the tank is filled to within an inch of the top.

Small aquariums up to 18 x 9 x 9 in. in size are adequate when space in the classroom is limited. In this case a pressed-steel framed tank or even an all-plastic tank would be satisfactory and should cost no more than £1. The most useful tank measures 24 x 12 x 12 in. A tank of this size holds in the region of 12 gallons of water when full and weighs about a hundredweight. Therefore it must be strongly made. We recommend angle iron framed tanks for anything of this size or larger. A fully glazed tank costs about £2 15s (see note on sources on page 158). Tanks of this size vary widely in cost and quality, but at the prices indicated, a perfectly satisfactory tank can be had. Some firms supply angle iron frames for those who prefer to glaze their own tank (see page 158). In this case the frame costs about 22s. Reinforced glass $\frac{1}{4}$ in. thick should be used for the base (cost about 3s 6d a sq ft) and 32 oz glass for the back, front, and sides (cost about 2s 9d a sq ft). Special aquarium putty may be bought from aquarists or, alternatively, metal casement putty may be used. About 2 lb will be needed for a 2 x 1 x 1 ft tank (say 2s 3d a lb). In making up an aquarium the cost of paint and varnish must be added to the above. There is therefore little to gain financially from making up one's own tank, apart from the sure knowledge that satisfactory materials have been used. Where the children are allowed to take a hand, much may be gained from the measuring, ordering of materials, and the actual construction.

A fully furnished aquarium, weighing over a hundredweight, must, as we have noted, be placed on a strong table (i.e. one capable of supporting an average adult). Two-tier angle iron stands measuring 24 x 12 x 36 in. cost about £2 10s.

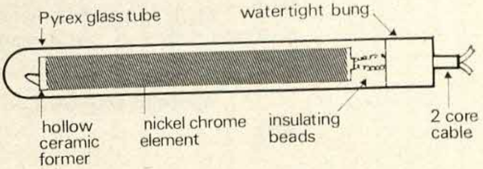


Fig. 37. A submersible heater.

HEATERS

Cheap submersible heaters, especially designed for use in aquariums, are obtainable. Current prices range from 7s 6d to 19s 6d. Several firms make heaters at about 10s 6d, which can be expected to give satisfactory service and are usually guaranteed for twelve months. This type of heater (figure 37, page 149) consists of a Pyrex type of glass tube enclosing a nickel chrome element wound around a ceramic former. A tightly fitting rubber or plastic bung, through which a two core cable is fitted, ensures complete waterproofing.

Care should be taken to ensure that the glass does not become cracked when handling. It is also important that the heater should not be in direct contact with the glass of the aquarium as the latter may crack with the heat. This type of heater has a limited life. It may be expected to last at least a year. After this time it is wise to retain it for further use during the summer months when failure will not usually result in losses. It is essential to carry a spare heater at all times so that speedy replacement can follow a failure. After some months of use it will be found that an encrustment has formed on the outside of the tube. This may be removed with a razor blade or knife. Care must be taken not to scratch the glass.

Heaters are sold in the following wattages: 25, 50, 75, 100, 125, 150, and 200. The price is the same, regardless of wattage.

It is difficult to give advice on the wattage required for an aquarium without knowing the average room temperature where it is to be kept. The wattage of the heater should take account of the size of the tank and the amount of work it is required to do, i.e. the atmospheric temperature with which it will have to cope. In general choose the less powerful heating unit so that failure of the thermostat does not result in the overheating of the water.

A simple formula for calculating the required wattage is as follows:

Allow two watts per gallon per 5 degrees Centigrade rise in temperature above the external temperature.

Example

To raise the temperature of a 24 x 12 x 12 in. tank from 10°C to 24°C:

$$\text{tank holds } \left(\frac{24 \times 12 \times 12}{277}\right) \text{ galls.} = 12 \text{ galls. approx.}$$

$$\text{wattage required} = (2 \times 12 \times 3)\ \text{W} = 72\ \text{W}.$$

THERMOSTAT

For use in schools we recommend the external fitting thermostat, preferably of the type which incorporates an earth connection. The reasons for preferring this type to those mentioned later is that (*a*) they are less likely to be affected by condensation, (*b*) they are easier to adjust, (*c*) they are safer electrically, and (*d*) they are less likely to suffer damage.

There are, however, some disadvantages which should be understood. The external fitting thermostat is held close to glass on the outside of the tank by means of a spring wire clip. A base plate conducts the heat through the aquarium side causing a reaction based on the principle of the bi-metallic strip. If the base plate is not in contact with the glass or if the water level in the tank falls below the level of the thermostat the latter will respond to the atmospheric temperature which usually means a rise in the water temperature. Once the thermostat has been adjusted to give the required temperature the adjustment knob should be taped down unless, as in the latest kinds available, a cover is provided. This is to stop children fiddling with it.

Current prices of this type of thermostat are listed as follows:

Constat External, 36s, Constat type QK, 25s.
Wizard External, 25s, Prockter, 36s.

Some of these thermostats are fitted with a neon light which glows when the current is flowing.

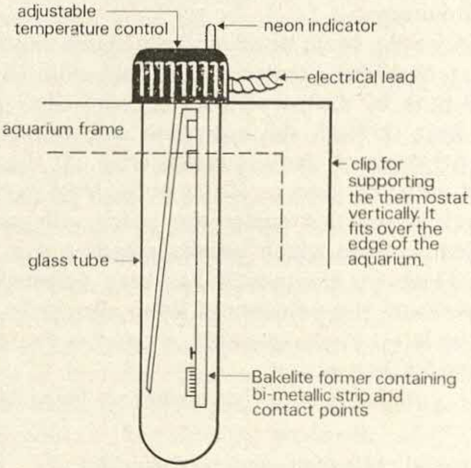
The other main type of thermostat is the semi-submersible. This type is suspended by means of a clip from the side of the frame so that the lower part is in the water (see figure 38).

This type, being in closer contact with the water, tends to give better control over its temperature. As with the external fitting thermostat, failure to maintain the water level in the aquarium will result in the thermostat reacting to the atmospheric temperature. Adjustment and regulation of the temperature can be done externally by means of a dial control. Disadvantages of this type of thermostat are (*a*) they are liable to become unserviceable owing to condensation, (*b*) being made of glass they are more likely to be broken, and (*c*) they may prevent a flush fitting of the light hood.

Prices range from 10s to 26s 6d. The lower priced types and those with internal adjustment are not recommended. Reliable thermostats of this kind may be bought for about £1. This type also may incorporate a neon indicator light.

Fig. 38. Method of installing a semi-submersible thermostat.

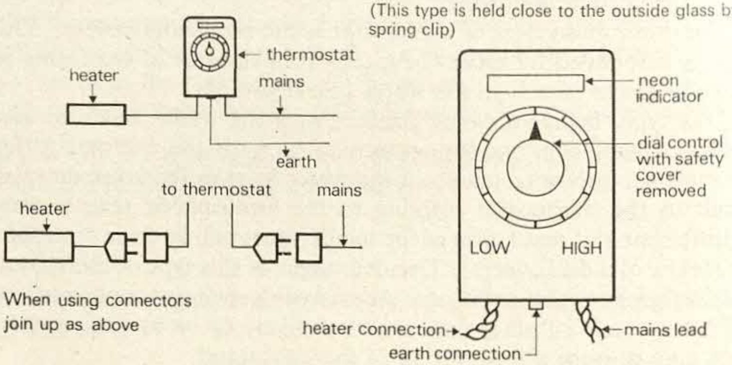
Es Es 'sentinel' Thermostat


adjustable temperature control
neon indicator
electrical lead
aquarium frame
clip for supporting the thermostat vertically. It fits over the edge of the aquarium.
glass tube
Bakelite former containing bi-metallic strip and contact points

Wiring diagram for heater and thermostat

Springfield Contact External Aquarium Thermostat Type ET5

(This type is held close to the outside glass by a spring clip)



When using connectors join up as above

Warning

It is essential to have the installation done or checked before use by a qualified electrician. The tank frame should be earthed and at all times when children are doing work, such as cleaning the inside glass, cleaning the aquarium floor, etc., the mains plug should be removed. As there is a danger that the plug is not replaced afterwards, it is helpful to hang a notice in a prominent place, to the effect that the service is disconnected.

THERMOMETER

The most satisfactory type of thermometer for everyday use in the aquarium is undoubtedly the circular, submersible type which may be attached to the glass by means of a sucker. It is an advantage to place the thermometer in such a position that the temperature required, as indicated on the dial of the instrument, is at twelve o'clock. In such a position it only needs a glance to see that the reading is normal or otherwise. Inevitably the question will be asked, 'Why does the thermometer stick to the glass?' Twice daily readings should be made of the water temperature. These should be recorded in a manner suitable to the age of the children. Practice should be given in the use of other types of thermometers. When using an external fitting thermostat it will be useful to record the room temperature at the same time as that of the water in the aquarium.

AERATOR

An aerator is not an essential piece of equipment although it is useful when an aquarium is overcrowded. It is useful in the culture of brine shrimps and for passing a gentle flow of water over the eggs of certain fish which are being raised artificially. Generally speaking, it is not needed where only a few tanks are kept. The main function of aeration is to circulate the water so that there is greater diffusion of gases at the surface. The entering air is passed through a diffuser stone so that the bubbles are very numerous, thus increasing the surface area exposed to the water and thus causing more air to be dissolved in the water in its passage to the surface. Fish accustomed to water which has been subjected to aeration may experience some discomfort when transferred to an aquarium where

TABLE 3 Notes on a selected list of tropical fish

Species	Food	Community tank suitability	Breeding
Guppy (*Lebistes reticulatus*) Price 1s 6d	Omnivorous	Adults (young may be eaten)	Viviparous (prolific)
Mollie (*Mollienisia* spp.) Price 3s 6d upwards	Mainly vegetarian. Dry food, e.g. chopped lettuce. Browses on algae	Adults	Viviparous
Platy *Xiphophorus maculatus* (formerly *Platypoecilus maculatus*) Price approx. 2s 6d	Omnivorous	Adults	Viviparous (prolific)
Swordtail (*Xiphophorus* spp.) Price approx. 2s 6d	Omnivorous	Males tend to bully each other. One to each tank	Viviparous
Zebra fish *Brachydanio rerio* Price approx. 5s	Omnivorous	Adults	Non-adhesive egg scatterer. 25° C
Three-spot gourami *Trichogaster trichopterus* Price approx. 5s (young)	Omnivorous. Enjoys live food	Large specimens may eat other small fish	Bubble nester 27° C
Siamese fighting fish *Betta splendens* Price approx. 10s-£2	Mainly live food	Only one male per tank	Bubble nester. 25° C
Egyptian mouthbreeder *Haplochromis multicolor* Price 10-15s	Live food	Fair. Sometimes attacks small fish	Mouthbreeder. 25° C

Temperature range	Other information
15-32° C	There are many types of guppy brought about by selective line breeding. If a quality such as particularly bright colouring is to be retained, care must be taken to discard poorly coloured males and to ensure early isolation of virgin females. Indiscriminate breeding will lead to a deterioration of the strain.
21-27° C	Gravid females have the ability to retain young for long periods if conditions are not right.
18-32° C	Many variations of colour are available. Cross breeding between the colour strains usually leads to a deterioration of the colour.
22-32° C	At first it is not possible to distinguish the sexes of this species. Later males develop a gonopodium and the lower rays of the tail fin develop into the 'sword'.
16-37° C	A lively fish which is always on the move. It is best seen in shoals. Easy to breed but is liable to eat the eggs unless precautions are taken to prevent this. The stripes are horizontal, not vertical as in the zebra.
20-29° C	Fairly easy to sex. The male has a longer and more pointed dorsal fin than the female. It is one of the easiest of bubble nesters to breed. Once the eggs are in the nest, the male takes sole charge of the care of the fry.
20-32° C	Two males placed side by side in glass containers will react in a most spectacular manner. A mirror held to a single male will cause a reaction. Fish will also jump to take white worms held just above the surface of the water. Their ability to take part of their air requirement at the surface enables one to confine individuals in small jars floating in the aquarium.
21-27° C	Much interest is created by the unusual method of protection of the eggs and young in the mouth of the female.

there is no aeration. It is the surface area of the container which is important to fish. The greater the surface area, the greater the amount of gaseous exchange. Thus a spherical container should be filled only to the widest part, if it is to be used for keeping fish or other aquatic creatures.

MISCELLANEOUS EQUIPMENT

Nets to transfer fish from one tank to another should be rectangular so that they will fit into corners of the tank, and about 6 in. wide, or larger. It is humane to use a large net which catches a fish first time rather than fiddle about with a tiny net from which the fish can usually escape.

Feeding rings are plastic or glass rings which float on the water surface. Their use is to retain small amounts of dried food so that these, as they become soaked, fall to the bottom from a restricted area. The fish soon learn where to expect food.

Lengths of rubber tubing are useful for filling and emptying tanks. Narrow bore tubing, about ¼ inch internal diameter, is best for filling tanks, because the flow from this size tube causes less disturbance to the tank. For emptying a tank a much wider tube is desirable, say ½ inch internal diameter. Obviously, the same result (i.e. rapid emptying) can be obtained by using several tubes of small diameter. Forceps a foot long, made of beechwood, are very useful for picking up objects from the bed of the tank. They are easily made.

Notes on selected fish

The list of fish in table 3 (pages 154-5) is given to help those who are making a start. Most of the fish listed are available from dealers. There are many other species and varieties usually available.

Notes on selected plants for the tropical aquarium

Although there are certain British species which thrive in tropical aquariums (e.g. *Elodea* and *Ceratophyllum*) we advise against introducing wild plants to the tropical tank because some may carry leeches or fungus spores which may cause damage. By all means use plants from the local pond in cold water tanks of a temporary kind. In that case, the insect larvae, leeches, and other organisms attached to the plants can be a centre of interest.

TABLE 4 A short list of plants suitable for a tropical tank

Name	Description
Sagittaria subulata	Grass-like, rooted, produces runners.
Vallisneria spiralis	Grass-like, rooted, produces runners.
Cabomba caroliniana	Fan-shaped leaves, finely divided, rooted.
Cryptocoryne spp.	Broad, dark green leaf blades on long stalks, rooted.
Hygrophila polysperma	Privet-like leaves, rooted.
Riccia spp.	Narrow, Y-forked fronds, a useful refuge for fish fry, floating.
Limnophila sessiliflora	Fan-shaped leaves arising in whorls, each finely divided. Resembles *Cabomba*. Slow-growing, but bushes out nicely, especially if the tips are pinched out occasionally.

There are many plants available for planting in a tropical tank. We list a very small number in table 4, these being easy to grow and widely available. See also pages 136-8.

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Sources of supply

Complete aquariums and other equipment may be obtained from dealers. Many firms advertise in the *Aquarist* magazine which is published monthly, price 2s 6d. This publication gives a Buyers' Guide listing retailers in many parts of the country who supply aquarists with fish, plants, and appliances.

FRAMES AND STANDS

J. E. Heeney, 52 Charter Street, Accrington.
Hockney Engineers, 1 Derwent Place, Bath Road, Leeds 11.
Dodmund Engineering Co., 43 Baker Avenue, Stratford on Avon.

CULTURES

Euglena, micro-worms, white worms, grindal worms, and the food on which to feed them are sold by E. Arnold, 80 Monega Road, London E7.

PLANTS

Many suppliers will be found from advertisements in the *Aquarist* magazine.

Chapter 5

Insects

General features of insects

N BRITAIN ALONE there are 20,000 recorded species of insect, and more are discovered every year. In the world, there are three-quarters of a million known species, and at a conservative estimate, probably a million species altogether. This is more than six times the number of all other animals. They are to be found in abundance everywhere, except the sea; and even here, there are a few species. Moreover, insects are astonishingly prolific. It has been estimated that if all the progeny of a single pair of flies lived and reproduced for four months there would be enough of them to cover the whole earth to a depth of forty-seven feet.

Some groups of animals remain largely unnoticed, but the insects are everywhere evident. Wasps and flies invade our homes by day and moths by night, drawn in by scents and light. We enjoy seeing tortoiseshells and other splendid butterflies. But shops carry more and more insecticides, which we use with too little regard for those species we might not wish to harm. And in spite of these destructive measures, the insect world survives. It has been affected by man's intervention, but is still eminently adaptable and remains an important factor in our environment. Insects seem to be keeping pace with our technology; new forms are continually emerging, resistant to the latest insecticides or better adapted to life in sooty suburbs.

Insects belong to the phylum or group of invertebrates known as arthropods. They all have a hard jointed outer case or exoskeleton

which they shed for a new one as they grow larger. The spe
features of an insect's body are:

1. It is divided into three distinct parts—head, thorax, and abdom
2. It has three pairs of jointed legs, usually two pairs of wings, all attached to the thorax; and one pair of antennae, attached to the head.

(It differs from another class of arthropods, the spider, in that the body of the latter is divided into two, has four pairs of legs, a no wings.)

But this zoological definition does not tell us why the insect is o of the most successful organisms.

SKIN (CUTICLE)

To understand this, we need to examine the structure of the inse body. Most important is the insect's skin. This is called an e skeleton or cuticle. In some ways it resembles a thin sheet of plas It combines great strength with flexibility and lightness, taking form of tough plates connected by thinner, slightly elastic ar The weevil's cuticle (figure 39) is a strong armour-plating, whil caterpillar's is less obvious, but still protective. The cuticle is alm waterproof, perhaps the crucial property of the insect's formula survival. All living things need water, which makes up the bulk of body tissues. The conservation of the water within the body is of paramount importance to land animals, whose access to supplies is often intermittent. The cuticle keeps the insect dry and prevents it from losing moisture. Thus insects can live in very hot places without risk of drying up. Of course, the cuticle does not offer total protection against extremes of heat. Honey bees die unless they have access to watery liquids such as nectar. On the other hand,

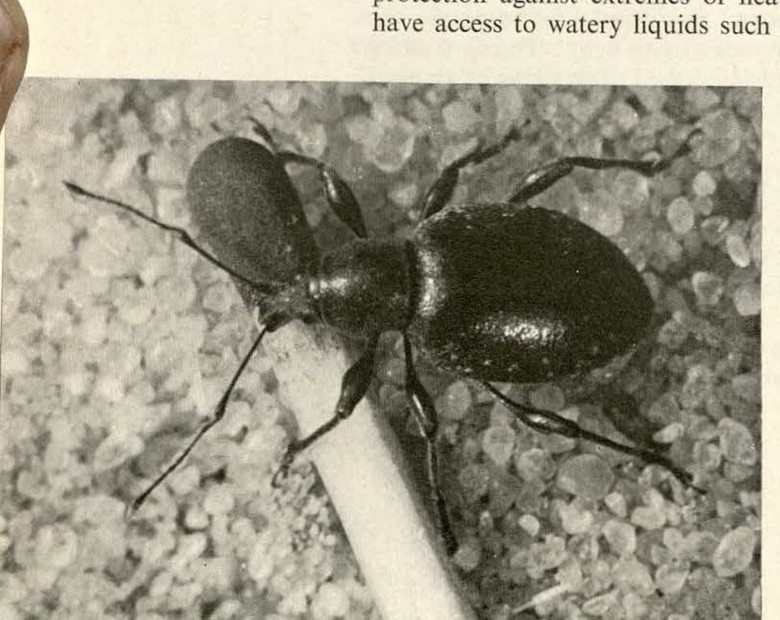


Fig. 39. A weevil.

mealworms can live on dry materials such as stored grain or flour and obtain enough moisture from these.

The insect cuticle is made to measure and allows only a limited amount of growth. At intervals, therefore, it has to be partly absorbed and partly shed. A larger new cuticle develops by an immensely intricate process beneath the old one. The newly exposed cuticle is soft at first, and the insect is particularly vulnerable to attack at this stage. Many insects stop feeding and lie up for several days during the moulting period.

LOCOMOTION

Land insects have solved the major problem of locomotion on land and in the air. The body of an aquatic animal is largely supported by the surrounding water. Air is less dense and gives much less support. Animals move most effectively on land when their bodies are held clear of the ground, supported by muscles attached to some form of skeleton. The insect has no bones; there are internal projections in the cuticle which provide points of attachment for muscles to move limbs and other parts of the body. The insect has three pairs of jointed walking limbs. The muscles within the legs are attached in pairs longitudinally across each joint: when one muscle contracts its partner relaxes and the limb bends or straightens at the joint.

What is remarkable about the insect's powers of flight is not so much the speed as the degree of control exercised by certain species. Hover flies can fly forwards, backwards, up, and down, or remain stationary in mid-air. It is even more remarkable that there are no muscles and tendons pulling on the various parts of the wing itself. Both movement and control of the wings' inclination, and therefore of direction of flight, are brought about by muscles in the chest or thorax. Some of these are attached to the base of the wing; others move the wing indirectly by pulling on the skin of the thorax. Each wing is a double layer of cuticle. The so-called 'veins' which support the cuticle are thick-walled tubes of the same material containing air passages and blood. When a butterfly, newly emerged from the pupa, or chrysalis, expands its wings, it does so by pumping blood into them.

Winged insects can search for food and disperse themselves over a wide area. However, some of the most widely dispersed insects, such as greenfly and the other aphids, are weak fliers. These are small insects which are carried by wind and convection currents, sometimes for hundreds of miles.

RESPIRATION

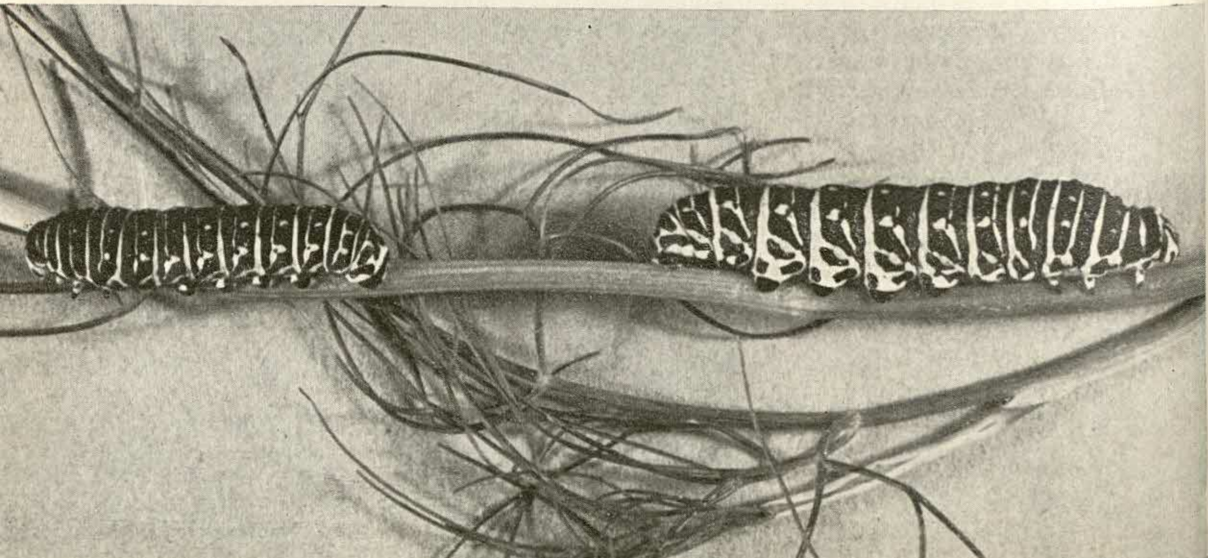
The insect's respiratory system is another feature which adapts it especially well to terrestrial life. Unlike the vertebrates, its bloodstream does not convey oxygen to the tissues. Oxygen enters through small openings in the exoskeleton called spiracles (plate 9) and travels directly to the bodily organs along intricately branching tubes called tracheae. The interior terminal portions of the tracheae are moist, thus enabling the exchange of gases to take place in solution. Oxygen is absorbed and carbon dioxide escapes by the same path. In vertebrates, far more of the respiratory system is exposed. Since it is moist, it is a potential source of water loss. But the insect's respiratory system is so slightly exposed that it prevents water loss. Some insects can even close the spiracles in especially dry conditions. The larger insects also ventilate the tracheae, creating air movements by contracting the muscles of the abdomen.

The exoskeleton of some aquatic insects is adapted to take oxygen into the tracheae directly from the water. But many insects, like the water beetle, retain a respiratory system more appropriate to a terrestrial form. They visit the surface periodically to take in fresh air. In such insects, there is a smaller number of active spiracles, and the apertures are guarded by hairs to prevent the entry of water.

LIFE CYCLE

In flies, beetles, moths, and butterflies the newly hatched insect bears little resemblance to the adult. These young insects are variously known as maggots (flies), grubs (beetles), and caterpillars (butterflies and moths), although the term larvae is applied to all of them (figure 40). A larva often feeds voraciously, and moults several times; each time it increases in size. The change from larva

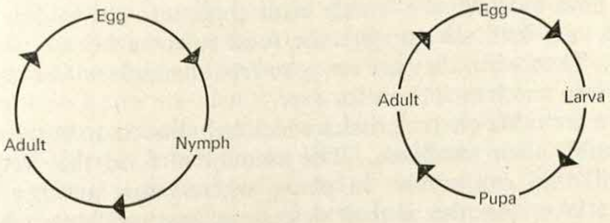
Fig. 40. Larvae of the swallow-tail butterfly.



to adult, known as metamorphosis, occurs during a so-called resting stage, the pupa or chrysalis stage. The outward events are quite straightforward. A fully grown larva sheds its skin to reveal, not another larva, but a different structure, which is more or less cigar-shaped, has limited powers of movement and is unable to feed. This is the pupa (plate 12). Then, after a period ranging in different species from a few days to several months, the pupal case cracks open and an adult insect emerges. This transformation can easily be followed in the classroom. What cannot be observed are the changes occurring within the pupa which transform a caterpillar into a butterfly or a maggot into a housefly. The pupa is a living workshop within which the larval structures are almost entirely dismantled and the materials are used in the construction of adult parts. The change is so great that one would not relate the two stages with each other without having actually observed the process.

How this strange metamorphosis has evolved is open to conjecture. Clearly, during the larval stage the whole emphasis is on feeding. The larva accumulates the materials which are eventually built into the adult, whereas the adult's chief function is reproduction and the dispersal of the species. Adaptation to these different roles may be the reason that these strikingly different forms have survived, but we cannot explain yet how it has come about.

The two chief types of insect life cycle



Incomplete metamorphosis *Complete metamorphosis*

Not all insects follow this sequence of development from egg to larva to pupa to adult. The young stages of hatched grasshoppers, locusts, stick insects, may flies, dragon flies, and water bugs, known as nymphs, resemble the adults, although they are smaller and lack both wings and reproductive organs (figures 44 and 45). A nymph moults several times, increasing in size at each step. In the last few moults it gradually develops adult features. This smooth transition to the adult stage without a pupal stage is called incomplete metamorphosis.

OTHER FEATURES

An element in the survival of an organism is its ability to travel to a habitat where it can obtain food and shelter. Here, special patterns of behaviour besides mobility come into play. A spectacular example is the painted lady butterfly which migrates regularly each year from North Africa to England. In other insects, such skill in finding food and shelter is less obvious. The grubs of the sexton beetle hatch out in an underground tomb the parents have prepared around the carcass of a mouse or nestling bird or other small mammal. This carcass provides them with food, moisture, shelter, shade, and coolness until they have pupated and emerge as flying beetles. But they still have to make their way through the dried outer surface of the meat to the moist, edible flesh within. And, as adults, they will have to find a similar habitat before they may reproduce.

In fact, the adult sexton beetle is brought into the open by its power to smell the gases drifting from a decaying corpse. It flies in widening circles until it finds the corpse, at which point, of course, it distinguishes it from its surroundings by sight, as well as smell. It has been known to travel two miles in this process. Then it fights off other animals or sexton beetles of its own sex and takes a mate of the opposite sex from among the other comers. They both drag the food, which gets skinned in the process, from four to nine inches underground, construct the 'tomb' so there is room to crawl around it, and reproduce. The male leaves as egg-laying begins, each egg being deposited in a chamber in the walls of the tomb. When the larvae have hatched, the female leads them into the middle of the carcass. At first, she conveys the food to them herself, with her mouth. Then when they are ready to feed themselves, she climbs to the surface and leaves them for ever.

There are other characteristics which help insects to survive. One is probably their smallness. The amount of food they require is so small they can survive in places where many another animal would starve. Another is their defence against predators which eat them—for example, birds, spiders, frogs, toads, insect-eating mammals, and even other insects. Some insects, like ants, fight with their mandibles; others sting, like bees and wasps. Others have a feature which looks formidable even if it is not, like the huge (but immobile) jaws of the male stag beetle. Others are distasteful to birds and other animals and have bright colouring, like the yellow-and-black spotted caterpillar of the large white butterfly, which predators recognize and avoid. Other insects can run, jump, or fly away swiftly from danger.

Some have a colouring that matches their background. The pupa of the large white butterfly matches the cabbage leaf it is attached to. Others resemble something else, as *Carausius morosus* resembles its more familiar namesake, the stick.

Perhaps the most sophisticated factor for success in insects is the social sense which some posses. Ants, wasps, and bees (page 199) live in communities and divide the labour of the community according to what might almost be called a class structure. Thus, the queen bee lays the eggs in a hive, the drones or males fertilize her, and the sterile females or workers make the cells and feed the inmates of the hive. There is provision for succession when the queen's egg-laying life is exhausted. The regime in the hive continues after the majority of the hive has swarmed off (possibly because it was over-crowded) to form a new one, leaving a colony in the rear in the old one.

OPPORTUNITIES IN TEACHING

Insect studies may arise when children find a specimen and bring it to school, or the teacher may create these opportunities by encouraging them to search in particular places at certain times of the year. Tables 1-3 (pages 182-7) indicate where and when to look for the eggs and larvae of some common butterflies and moths. But it is sometimes useful to buy the young stages of insects from dealers. This has the advantage that specimens are already identified and suitable provision can be made for feeding them. We describe on pages 170-3 some simple general purpose containers and cages, which can be quickly adapted to meet the needs of different insects.

Whatever the source of an insect brought into the classroom, it is important to know its identity since this will make it possible to consult reference books to find out how to provide for its habits. In fact, if there is much doubt about its identity and habits it is kinder to release it after a brief period of observation. To avoid this, children should be encouraged to notice the exact place where they found an insect, and how it behaved, as this frequently provides a clue to its needs. A caterpillar found walking across the road, not on a plant, is probably seeking a spot to pupate and would no longer require a supply of food. It should rather be provided with dry peat in case it should be the type that burrows at this stage, and with branching twigs, in case it should prefer to climb to pupate.

When we know what an insect is, we can ask:

Is it an adult? What does it eat and drink?

What conditions does it appear to need for growth?

These questions, of course, are not necessarily those asked by children, and the fascination of insect studies lies in the enormous scope they offer for observation, investigation, and experiment. We include below a selection of questions asked by teachers and children relating to the eggs and caterpillars of butterflies and moths. This list is by no means exhaustive.

Questions asked by teachers and children

Eggs—How many eggs does a female lay? Average number laid. Do large females lay most eggs? How many eggs are laid by day? by night? Does the female select a site carefully? Where do the eggs come from? Do females lay eggs if they have not mated? Do they hatch? What about stick insects? Does it matter if eggs are rained on? Are eggs of moths and butterflies waterproof? How long does it take for the eggs to hatch? Do the first laid eggs hatch first? Do eggs develop more quickly in warm conditions? If we keep eggs cold, do they hatch? Does sunlight hurt the eggs? Do baby caterpillars tell one another when they are going to hatch? Is there any reason why the female lays eggs in neat rows? How many eggs hatch? At what time of day or night do the eggs hatch?

Larvae—How do larvae find food? Can they distinguish between the upper and lower surfaces of a leaf? What happens to the egg shell? When do the larvae start to eat? How long before they produce their first droppings? Do the larvae all choose the same food when given a choice? How do they tell the difference? Do they grow before the first moult? When do they moult? Where do they moult? Do they always hang head downwards when moulting? Do they always walk about before a moult? How much do they eat? How much is waste? Do they drink? Does a food plant become 'waterlogged' when kept in a jar of water? Are damp conditions harmful? If so, why? When larvae are said to eat a variety of foods, do they voluntarily change their diets? Do some larvae eat only at night? Can we fool them into thinking it is night-time? What stimulates larvae to hibernate? decrease in day length? falling temperatures? failure of food supply?

British and European butterflies and moths

Of all insects, butterflies and moths are especially suitable for classrooms. They need only very simple equipment. Eggs of some species can be bought from dealers or found by looking in the right places at the right time. The following notes will help those who have little experience with butterflies and moths.

THE EGG

Collecting eggs

Eggs are more often found by random rather than deliberate searching, but note that certain plants are favoured by a good many species of moth. Some trees are always worth searching: alder, beech, birch, elm, hawthorn, oak, and sallow. The last three are particularly favoured. Many moth caterpillars eat chickweed and dandelion leaves, while several butterfly caterpillars prefer common stinging nettle.

Looking after eggs

Under normal conditions, eggs will hatch after two to three weeks. They should be kept at room temperature in a shady spot not subject to rapid changes of temperature. Eggs laid on plants growing in pots should be left there. It is easiest to slip a plastic cylinder and cap over the plant before the eggs hatch. If the eggs have been laid on cut shoots which will not stay fresh, it is best to transfer each leaf bearing eggs to a transparent plastic pill box. Eggs should be handled as little as possible. If they are laid on cardboard or muslin, cut out the piece of the box or fabric to which the eggs are attached and handle this rather than the eggs. When the eggs hatch, but not before, fresh leaves can be placed in the pill box. Eggs kept in pill boxes should be examined daily when hatching is expected so that the young larvae are not long without food. Eggs of some species darken when they are about to hatch. Eggs laid in the autumn may not hatch until spring (see tables 1 and 2, pages 182-5). These should be stored in pill boxes in an unheated cellar or shed, and brought indoors during late March or early April to await hatching.

The same routine should be followed for eggs bought from dealers. Resting eggs should be kept cool during the winter; otherwise they may hatch at a time when a suitable food plant is not available.

THE LARVA

Collecting larvae

Larvae are easier to find, as they are larger, but many are well camouflaged. Deliberate searching is usually less successful than the collecting method known as 'beating'. A sheet of plastic, cloth, or paper is spread beneath a bough, which is then struck with a stick. The jolt shakes off most caterpillars onto the sheet. Some larvae feed at night and are more easily caught by the same method in the evening or early morning.

Stinging nettles are worth searching in May and June for the larvae of small tortoiseshell and peacock butterflies. The young caterpillars are gregarious. They build conspicuous communal webs of silk which bind the nettle leaves together, particularly those at the tips of a shoot. During the final stages of growth the caterpillars develop solitary habits.

Some moths have web-spinning caterpillars: for instance, lackey and yellow-tail moths. Eggs of both species are laid on hawthorn, blackthorn, and cultivated fruit trees in July and August. Yellow-tail eggs hatch within a fortnight, while lackey eggs remain dormant until spring. In both species, development is completed in May and June. The caterpillars are brightly coloured and hairy, those of the yellow-tail particularly so. It should be noted that a few people develop a skin rash after handling hairy caterpillars. The yellow-tail caterpillar is one of the species known to have this effect. Others include the reddish-brown caterpillar of the fox moth, which is sometimes found in autumn wandering in search of a place to hibernate, the black arches, the gipsy, the vapourer, and the northern eggar moth caterpillars.

Handling larvae

The best method of handling caterpillars is to pick up a piece of the food plant to which the caterpillar is clinging or, failing this, to manipulate the larva into a spoon with a soft paintbrush (figure 41). In this way there is no danger of skin infections or of damaging the caterpillars.

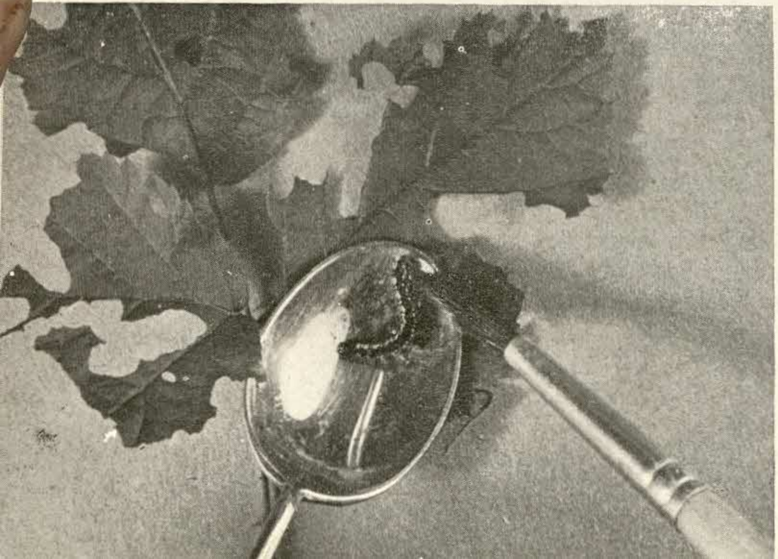


Fig. 41. Handling a small caterpillar with a paintbrush and a spoon.

Quite a large proportion of caterpillars found in the wild state are parasitized with grubs of ichneumon flies. Usually there is no outward sign that anything is wrong until the caterpillar pupates. Then, in many cases, when the ichneumon fly grubs have completed their larval development within the caterpillar's body, they tunnel out of the host and pupate alongside. The small yellow, fluffy balls commonly associated with pupating caterpillars of the large white butterfly, are the pupae of an ichneumon fly, *Apanteles glomeratus*. The female *Apanteles* lays a large number of eggs within the body of a single caterpillar. *Apanteles* grubs feed on the body tissues of the caterpillar, but they select the less vital organs first so that the parasitized caterpillar does not die until it is about to pupate. Then the *Apanteles* grubs emerge, spin their own cocoons, and pupate. Ichneumon flies are not really flies, but belong to the same family as wasps and bees. Thus they have two pairs of wings as against the single pair possessed by true flies.

The ichneumons and related parasitic insects play a most important part in controlling the numbers of insects. Some have highly developed sensory systems which enable them to find hosts in concealed positions. For instance, the largest British ichneumon, *Rhyssa persuasoria*, is able to detect, by sound or by a tactile sense of vibration, the larva of a wood wasp tunnelling in the wood of pine trees. *Rhyssa* drills through the wood to lay her egg precisely in the victim's body. But ichneumons themselves are subject to parasitic attack. The larvae of *Apanteles*, previously mentioned, are sometimes parasitized by the still smaller grubs of another species of ichneumon. These feed on the larger ichneumon grub and eventually kill it. Nor does the story end there, for still smaller insects, the species of chalcid wasp, attack and kill the parasites of the parasites. It is always worth while keeping some of the yellow cocoons found near large white butterfly caterpillars just to see what does emerge!

Rearing larvae

Small transparent plastic boxes with tight fitting lids are ideal for young larvae because they cannot stray far from the food in such a confined space. Food stays reasonably fresh for several days in a closed box. But we advise a daily change of food plant particularly while the larvae are young. The best technique is to introduce a small amount of fresh foliage into the box on top of the old. After half an hour or so, most of the larvae will have crawled onto the fresh leaves, and these shoots can be placed in a clean, dry box without handling the larvae directly. Inspect any larvae remaining in the dirty box, looking carefully to see if any of these larvae are attached to the box or to leaves by silken threads. If so they have begun the process of moulting and should not be disturbed. The box should be cleaned as far as possible and a little fresh food introduced. When the larvae have finished moulting they will wander about in search of food. They can then be returned to their fellows.

As a general rule, condensation inside a cage should be avoided. Apart from reducing visibility, the water droplets encourage the growth of fungi and may trap and drown tiny insects. Condensation usually occurs when a poorly ventilated cage containing plant material is exposed to sunlight. The leaves give off more water vapour and may cause saturation of the atmosphere within the cage. For this reason, cages should not be placed in sunlight. Cages that are well ventilated are less likely to have condensation problems.

Older larvae can be kept in large plastic boxes or plastic cylinder cages (see below).

Cages for larvae

Small plastic boxes have already been mentioned as very suitable for eggs and newly hatched larvae. Empty Lyons coffee tins supplied with plastic lids are very suitable, cheaper substitutes and, if ventilation is required, it is a simple matter to cut a hole in the lid with scissors and cover it with perforated zinc or nylon mesh stuck down with Evo-Stik.

For rearing large numbers of insects, plastic lunch boxes measuring about 12 x 6 x 3 in. are useful but expensive (about 10s). A cheaper alternative is a 'cat litter' plastic tray, costing about 4s, covered with a sheet of glass. The edges of the glass are bound with Sellotape. Polythene washing-up bowls are also worth a trial. A cardboard shoe box makes an effective temporary cage. A rectangle of clear plastic should be stuck over a hole made in the lid. Ventilation holes are pierced in the sides of the box with a pointed instrument. Two elastic bands hold the lid in place. With all the above cages, fresh food is placed in the container every two or three days and waste material removed. In general, these cages are not ventilated since this helps to keep the food fresh for a longer period; but even so, they require frequent attention.

Plastic cylinder cages

Cages in the form of clear plastic cylinders give good visibility. Since they are tall, they are the right shape for leafy twigs standing upright in water bottles. The food plant, being supplied with water, needs changing less frequently, perhaps once a week. It is possible to ventilate this type of cage and also provide suitable conditions for pupation. Cleared X-ray plates are a cheap source of transparent plastic sheet suitable for these cages. They can sometimes be obtained from the radiography department of a local hospital. They may be purchased from Don Gresswell Ltd., Bridge House, Grange Park, London N21. (Cost 3s 6d per dozen sheets.) Common sizes of sheet are 15 x 12 in. or 17 x 14 in. The latter size is large enough to make a cylinder 12 in. long with a diameter of 5 in.

Construction of plastic cylinder cages

Five types of cylinder cages are illustrated in figure 42. Plastic plant pot saucers are used for top and bottom of the first four. These saucers are available in various sizes. They are accurately moulded to fit snugly together or into the top of a plastic plant pot of appropriate size. A saucer 5 in. in diameter costs about 7d and a pot 9d. A large hole may be cut in the saucer, using a 'Toga' tank cutter held in a vice. The hole can be covered with perforated zinc stuck down with Evo-Stik. One advantage of these cages is that the cylinder may be dismantled at the end of the season and stored flat. The cylinders illustrated are 5 inches in diameter and the following descriptions refer to these. Cylinders can, of course, be made to fit any size of plant pot saucer.

Type (*a*)—The cylinder is formed from a piece of acetate sheet measuring 16 x 10 in. This is folded into a cylinder with a ½ in. overlap and held temporarily with paper clips. After checking that the cylinder will slide inside a 5 in. diameter plant pot saucer, stick the overlapping edges together with Sellotape, both outside and inside the cylinder. It is not worth while using expensive forms of sticky tape since ordinary Sellotape lasts for a season and the cylinder is best dismantled and stored flat over winter. All the cylinders illustrated in figures 42a-d are made in the same way.

Type (a) has a plant pot saucer at the top and bottom and is the simplest form of cylinder cage. There is no ventilation and the plant is not provided with water. This cage is quite satisfactory, provided it is kept in the shade.

Type (*b*)—This is similar to (*a*) with the addition of an extra saucer, having the base removed and a mesh floor fitted in its place. The caterpillars' droppings fall through the mesh into the lower saucer from which they can be easily removed. Perforated zinc is suitable for small caterpillars and Netlon ¼ in. mesh is best for larger caterpillars whose droppings would not pass through the small holes in the perforated zinc.

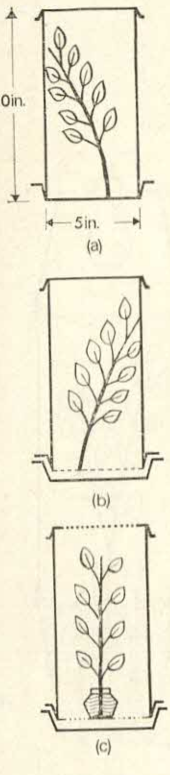
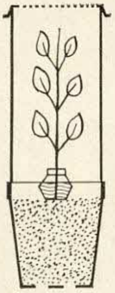


Fig. 42 (a), (b), (c), (d)—overleaf. Types of plastic cylinder cages.



(d)

Type (*c*)—This is similar to (*b*) with the addition of a small bottle, such as an ink bottle, containing water for the food plant. A hole $\frac{1}{4}$ in. in diameter is drilled in the lid of the bottle. With this arrangement the food plant keeps fresh for longer periods. The top plant pot saucer may be fitted with a perforated zinc disc to ventilate the cage.

Type (*d*)—Some caterpillars pupate below ground. This cage contains damp peat for such caterpillars, the base being a plant pot 5 inches in diameter.

Perspex cylinder cage

Perspex cylinders, though expensive, can be used to make cages similar to the cellulose acetate types, but of a stronger, more permanent nature. Various diameters of cylinder may be obtained from Moon Aircraft Ltd., Clift Works, Box, Wilts. The most useful diameters are $3\frac{1}{2}$ in., 5 in., and 6 in. A 12 in. length of tube, 6 in. in diameter with a wall $\frac{1}{8}$ in. thick, costs 17s 6d. The cylinder cage illustrated in figure 42e is suitable for rearing those tropical silkmoth caterpillars which need hot, humid conditions. The top, a 6 in. plant pot, is fitted with a bayonet-type lamp holder and a 15 or 25 W lamp. The base, another similar plant pot, contains peat and a water bottle to hold the food plant.

To construct this cage, the following materials are required:

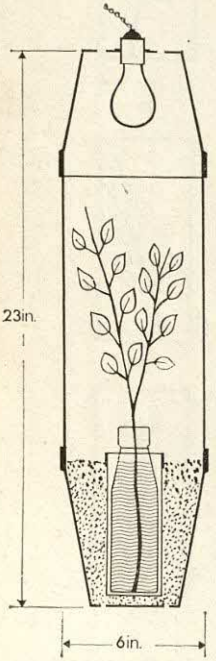
2 plastic plant pots, 6 in. in diameter
1 bayonet-type lamp socket, flex and plug.
1 25 W lamp
1 Perspex tube, 12 x 6$\frac{1}{8}$ in. wall
1 'squeezy' bottle
1 tonic water bottle to fit inside 'squeezy' bottle
1 plastic pill box lid, $2\frac{1}{2}$ in. in diameter
perforated zinc, 4 in. in diameter

Cut a $1\frac{1}{8}$ in. diameter hole in the centre of the upper plant pot. Fit the bayonet lamp holder.

Remove the top from a 'squeezy' bottle, leaving about 6 in. to form a jacket around the food plant water bottle.

Cut a $1\frac{1}{4}$ in. diameter hole in the pill box lid. This fits over the sleeve and prevents debris or caterpillars falling between the bottle and sleeve.

A circle of perforated zinc placed in the lower plant pot provides a level surface for the bottles and prevents peat from falling through the drainage holes in the plant pot.



(e)

Fig. 42 (e). Perspex cylinder cage.

Sleeve cages

All the British butterflies and moths and some tropical silkmoths can be reared out of doors on the appropriate growing food plant by enclosing the caterpillars on a suitable branch within a sleeve of muslin or other mesh. This can be of any size, depending on the numbers of larvae reared, and on the size of branch to be enclosed. A convenient size for most purposes is 36 x 12 in. Some commercial breeders use enormous sleeves to enclose whole saplings. The sleeve is slipped over a branch and tied at the base. Eggs or larvae are introduced and the top is then tied. This arrangement prevents the caterpillars from straying, but provides them with fresh leaves, and virtually natural conditions of ventilation and light. The sleeves need inspecting regularly. When the leaves are almost eaten, the sleeve should be transferred to another branch. At the same time, it might be necessary to empty the sleeve of droppings and other debris. The larvae of some species fall into the sleeve when the branch is tapped so that transfer is quite simple. If the larvae cling to the old branch, this should be snipped off and transferred with the sleeve into the new position. The caterpillars will eventually find their own way to the fresh leaves. This method of transfer is better than attempting to remove the caterpillars by hand.

Sleeves have the drawback that the contents are not readily visible. Black nylon mesh sleeves largely overcome this difficulty, but birds, too, can see through the mesh, and may peck at the caterpillars. On the whole, white muslin sleeves are most appropriate for rearing large numbers of caterpillars out of doors with the minimum of attention.

THE PUPA

Collecting pupae

Pupae may sometimes be found in leaf litter or buried in the soil at the foot of trees such as oak or birch. Many species hibernate in the pupal stage, so pupa digging is usually successful in winter.

Looking after pupae of butterflies and moths

Caterpillars pupate, either in the soil or elsewhere and then spend a variable amount of time in the pupal stage. Some emerge as adults after a few weeks. Others remain quiescent for much longer periods, perhaps through the winter. Information about the pupation habits of species kept in captivity may be available from reference books.

If so, appropriate preparations may be made. If the larva is known to pupate underground or in leaf litter, a layer of moist peat or bulb fibre should be placed in the bottom of the cage. Plastic cylinder cages with plant pot bases are very suitable for this purpose. When the larvae have disappeared beneath the peat they should be left strictly alone for about two weeks. This is to give the larva time to pupate. Then they should be transferred either to emergence cages or plastic boxes with lids, according to whether they are expected to complete development quickly or slowly.

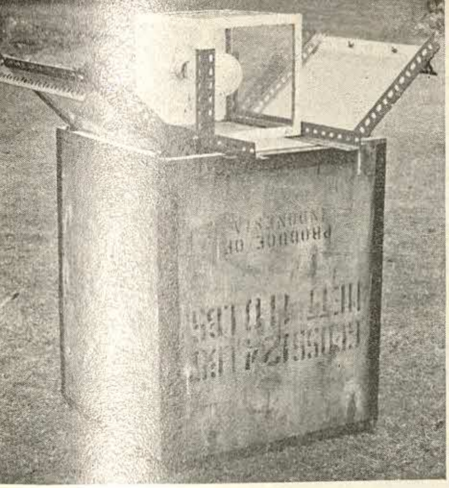
Those larvae known to spin cocoons among foliage should be provided with twigs, straws, or similar materials to simulate natural conditions. They, too, should be left undisturbed for at least two weeks after the cocoons are spun. Autumn-formed pupae that will not complete their development until spring should be placed in a box with a tightly fitted lid kept in a cool, frostproof place such as a cellar. Inside a closed box, a pupa will lose water very slowly and will probably escape death through dehydration. The pupae should not be disturbed until late March or April when they should be brought into a room with a temperature of roughly 16°C. At this stage they should be transferred to an emergence cage. This should have walls of a kind that will enable the insect to take a firm grip while the wings are expanded and dried. Black nylon mesh is favoured by many breeders.

The pupae or cocoons should be placed on a layer of damp peat or similar material. Daily spraying with water is recommended to prevent the pupae from drying out. Some stout sticks should be propped against the side of the cage for the adults to hang from while they expand and dry their wings after emerging.

THE ADULT

Collecting adults

Most adult moths are active only at night, and spend the day concealed in vegetation or perhaps under the eaves of a building. Many species are attracted by light and may be caught in some form of light trap. The simplest method is to place a 100 watt lamp in front of an open window on a summer evening. Moths and other insects, attracted by the light, will fly into the room where they may be caught. This method has two drawbacks. The collector must stay awake late, as some moths do not take wing until the small hours. Furthermore, he will have hundreds of tiny insects crawling about on the ceiling before the night is over. Fortunately, most of these will find their way out again by morning.



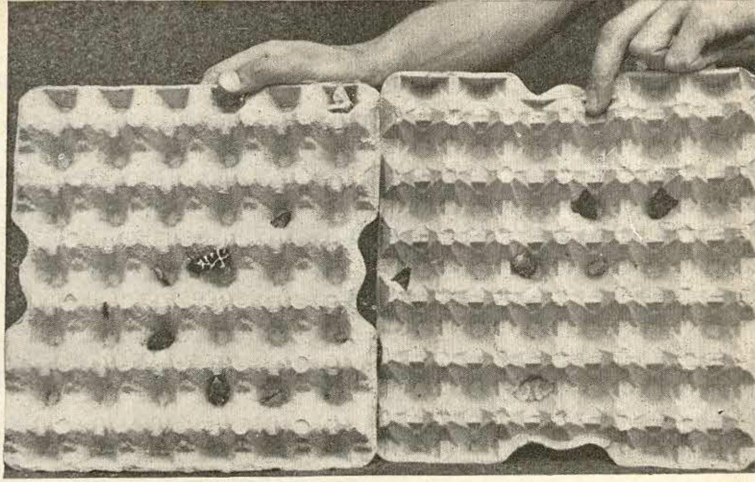


Fig. 43 (a). (*Left*) Home-made mercury vapour moth trap.

Fig. 43 (b). (*Right*) Moths resting in the egg crates which were stacked in the tea chest of the moth trap.

One type of moth trap which catches moths automatically is illustrated in figure 43a. The light source is a mercury vapour lamp. An ordinary tungsten filament lamp is satisfactory but better results are obtained with the mercury vapour lamp because it emits more ultra-violet rays, which are particularly attractive to moths. In this home-made trap, the lamp is protected from the weather by a biscuit tin fitted with glass sides and top. Moths fly towards the light, strike a glass pane, and fall into the tea chest. They crawl into the cavities of egg boxes stacked within the chest and lie there, inert, to be collected in the early morning when they are usually lethargic and easily handled (figure 43b). Avoid staring at the mercury vapour lamp since the eyes may be damaged.

This method of collecting should be used with discretion since so many moths can be caught—far more than by other methods. Most, if not all, of them should be released again, preferably at dusk, on the same day. They should be placed in a hedgerow or other sheltered spot *some distance from the moth trap*. This precaution is very necessary since birds rapidly associate the trap with moths if these are left lying around nearby.

These methods will not, of course, catch butterflies which are on the wing during the day, and recourse must be had to the butterfly net. This must be deep and large, with a diameter of at least twelve inches. The fabric of the net must be strong yet soft and pliable. Black cotton mesh is better than synthetic fabrics which tend to be too stiff.

Cages for adult butterflies and moths

The same type of cage can be used for emergence and breeding. One can be easily made from a large lampshade frame covered with black nylon mesh. The roof of this cage is a sheet of hardboard, but any stiff material will do. The base is similar but not essential, since the frame can stand on an old table.

A collapsible nylon mesh cage is a useful alternative which occupies little space when stored flat. It is slightly more difficult to construct but can be bought from dealers for about 16s 6d (1966 prices).

Breeding moths in captivity

Many species of moth reproduce in captivity. They usually mate at night. Copulating moths often remain linked together for a day or so. They should be left undisturbed until they separate. Then the female can be transferred to a cardboard box such as a shoe box. She will usually lay eggs in this whether or not the food plant is present. The commoner hawk moths such as the poplar, lime, and eyed hawk moths behave in this way, the eggs being laid within a few days of mating. Sugar solution can be provided as described for butterflies (page 177), but some moths, including the three hawk moths mentioned, do not feed when adult.

It is worth while looking for females among the specimens found in the moth trap. Again, one must be able to identify the species so as to be able to provide a suitable food plant for the larvae. It is sensible to select a common, conspicuously marked species. The garden tiger moth, on the wing in July and August, is a good example. The simplest method of sexing these moths is to compare several individuals of the same species, looking particularly at the antennae and the abdomen, for these structures are often different in the two sexes. Male moths often have elaborately plumed antennae (to enable them to detect the females' scent), contrasting with the simpler structures found in the female. The male's abdomen is usually more slender or tapered than that of the female, which is fatter because it contains eggs (whether she has been fertilized yet or not).

Male moths tend to come towards light in greater numbers than females, and you should not be dismayed if the first few specimens compared are all identical within any one species. The chances are that they are all males. It seems that many female moths do not fly very far until they have mated. Then they take to the wing in search of suitable plants on which to lay eggs. So it is highly probable that a female moth taken in a light trap has already mated and will lay eggs within a few days. In captivity, female garden tiger moths will lay their neat batches of pale green eggs on the leaves of many kinds of plant or on the walls of their cage. You can provide for them very simply: a shoe box will be enough.

Breeding butterflies in captivity

Butterflies are active by day and, as a general rule, mate and lay eggs most readily in sunny, warm, but not hot, conditions. In captivity they require large, airy cages as described previously. These should, for preference, be cylindrical, since fluttering insects may damage their wings in the corners of angular cages.

Feeding adults—Bunches of flowers (e.g. buddleia, valerian, ox-eye daisy, etc.) placed inside the cage provide nectar for the butterflies. A useful tip is to arrange the flowers with their heads close to the top of the cage where the insects fluttering about are more likely to find them. When fresh flowers are not available a substitute food can be made from a ten per cent solution of sugar, or honey, and water. If a piece of cotton wool or other absorbent material soaked in the mixture is placed near the top of the cage, the butterflies may feed on this. Although the adults of all British butterflies are capable of feeding, their habits differ. The peacock, purple emperor, and grayling butterflies are known to feed on the sap exuding from damaged trees in preference to taking nectar from flowers. The purple emperor has been found at rest on carrion, taking the juices exuding from the carcass, having been attracted probably by the odour of decaying flesh.

Mating butterflies—Unlike moths, most butterflies stay paired for periods of no more than a couple of hours, sometimes less. They should not be disturbed during pairing, but when they separate the male can be removed so that the female can lay her eggs undisturbed.

Fresh, leafy shoots of the appropriate food plant should be included in the cage to stimulate egg laying. In contrast to some moths, butterflies usually select sites for laying eggs with some care. Many will lay eggs only on the appropriate larval food plant. The majority of British butterflies deposit their eggs singly, often one to a plant. Information about the egg-laying habits of commonly available species will be found in table 2, pages 184-5.

Tropical silkmoths

INTRODUCTION

Silkmoths make up the family of moths known as Saturniidae. Nearly all spin silken cocoons, but silkmoth caterpillars should not be confused with silkworms, which are the caterpillars of the mulberry-eating moth, *Bombyx mori.* The latter produce silken cocoons from which silk is manufactured, and have been bred for this purpose for hundreds of years. The silk the Saturniids produce is not suitable for commercial use on a large scale. However, tussore silk is obtained from the cocoon of the tussore silkmoth (*Antheraea mylitta*). The emperor moth is the sole British member of the Saturniid family and, although this uncommon insect is attractively marked, it cannot match the tropical silkmoths, many of which are larger and gorgeously coloured. These exotic moths are to be found in America, Africa, Asia, and the Far East. Their often bizarre shapes and vivid hues have always attracted the attention of collectors, who may pay high prices for a rare species.

Rearing and breeding exotic silkmoths make an absorbing hobby. If it has fewer devotees than the comparable pursuit of keeping exotic aquarium fishes, this is no reflection on any difficulties it presents. Indeed, much can be accomplished with little or no specialized equipment and at no great expense. Silkmoths will bring attractive colours and interesting shapes into the classroom. These can be a powerful stimulus to creative painting or modelling. The caterpillars grow to a large size, and the various parts of the body are more clearly visible than in our native species. One is left in no doubt as to the use and effectiveness of the jaws as a caterpillar audibly crunches its way through leaf after leaf. Six large silkmoth caterpillars will consume such vast amounts of leaf during a day that relatively crude weighing devices are enough to indicate the intake. Droppings tend to be large and dry so that these too may be collected and weighed or counted. The exciting events of moulting and cocoon spinning are easy to make out in such large insects. The adults of some species mate readily in captivity and egg laying follows shortly afterwards, so that the whole life cycle may be followed in school.

REARING TROPICAL SILKMOTHS

It is sensible to begin keeping silkmoths by buying eggs. Dealers also sell larvae and pupae, but they are more expensive. A dozen eggs will cost from 3s 6d to 7s, depending on the species. They should be ordered in January for delivery in May or June when food is plentiful. A few species such as the Indian moon moth and the Chinese oak silkmoth will eat evergreens and they can be reared during autumn and winter. The subspecies of ailanthus moth, *Philosamia cynthia ricini*, will reproduce at any time of the year if it is kept warm (22°C). Since the caterpillar of this species feeds on privet, there is usually no difficulty in obtaining food.

Eggs should be kept in closed boxes, such as plastic pill boxes, in a cool place, until supplies of food plant are available. Then the eggs should be kept at normal room temperatures. Generally speakiug, hatching occurs after about two weeks at room temperature. The eggs should be inspected frequently from this time for signs of hatching. Many eggs change colour, usually becoming darker, just before hatching. A few fresh leaves of the food plant should be placed in the box as soon as possible after hatching, preferably within 2-3 hours, and certainly not later than 12 hours after hatching. Newly hatched caterpillars sometimes eat the egg shell and generally start to eat the food plant within 2-3 days. It is not necessary to provide special ventilation for the box containing young caterpillars, as it will get enough when the lid is taken off to replenish food supplies. Tiny caterpillars are very fragile and they should not be handled if this can be avoided. Certainly the fingers, which are far too clumsy, should never be used for picking up caterpillars at this stage. They must be brushed on to a teaspoon with a small paintbrush if it is necessary to move them (figure 41), but it is usually enough to place fresh leaves on top of the old so that the larvae can make their own way on to the new food supply. It definitely helps them if the pill box is a small one so that they do not have to wander far before encountering food.

Pill boxes should be kept in the shade in a place where there are no rapid changes in temperature which might bring about heavy condensation of water on the sides of the box. The danger from such drops of moisture is that they might trap and drown tiny caterpillars. With larger specimens there is no problem. It is advisable to avoid high humidities at all times when keeping native British caterpillars, since these appear to be more susceptible to disease when reared in moist air. The exotic silkmoths do not suffer in this way, and indeed, some experienced breeders believe that caterpillars actually thrive in humid conditions, possibly because these more closely resemble the tropical climate of their native haunts. Thus, a satisfactory cage for the larger caterpillars is provided by a plastic lunch box with a well-fitting lid. Under these conditions, sprigs of food plant will remain fresh without a water supply for several days, by which time they will largely have been eaten. Nevertheless, we advise frequent cleaning and the introduction of fresh food plant, preferably daily. Cylinder cages (see page 170) are equally suitable. Droppings and other debris should be removed at least once a week, more frequently in the case of young caterpillars.

Most silkmoth larvae moult four times and then pupate. For a time before and after a moult, the larva does not feed. Generally it changes to a duller colour and assumes a hunched-up attitude. Some caterpillars attach themselves to a leaf at this time, and the firm anchorage helps them wriggle free from the old skin, which is cast off during the moulting process. Larvae which are moulting should not be disturbed until they begin feeding again. Some species consume part of the cast-off skin.

The fully grown larva seeks out a suitable spot for pupation and spins a large silk cocoon, sometimes attached to leaves or fastened to the cage walls. A favourite place is the angle between the lid and side walls of the container. It is wise to prevent this happening, since you may not be able to open the box without damaging the insect. Fortunately, there are almost always clear signs that the larva is about to pupate. The body colour becomes dull and the larva stops feeding. It may leave the food plant and wander about the cage. At this time, a false lid of strong paper may be fastened to the container so that if the larva chooses to spin a cocoon in contact with it, the rest of the paper may be cut away afterwards to give access to the box. Alternatively, the larva may be removed to a separate cardboard container such as a shoe box. It will take ten days or so to pupate inside the spun cocoon. Then, that part of the box with the cocoon attached may be cut away from the rest, and the cocoon can safely be moved and stored in a cool place. Plastic boxes or tins are satisfactory. The majority of species pupate in late summer or autumn and spend the winter in this stage: hibernating pupae should be kept in a cool place free from frost. But some larvae which pupate in August or early September may emerge as adults in the autumn, especially those species from equatorial regions where the distinction between summer and winter is not so clear cut as in the temperate zones. If these moths breed and lay eggs which hatch at this time of the year, the rearer may find it difficult to obtain suitable food. Fortunately, some of the species which breed throughout the year feed on evergreens which are always available.

Preparations for the emergence of moths from pupae should be made in March, since this may be expected from April onwards.

Newly emerged adults require space to expand their wings and something to cling to. A lamp-shade frame covered with nylon net makes a satisfactory cage (see page 176). The pupae should be placed in a tray of damp peat on the floor of the cage and left in a warm place. Alternatively, cocoons may be attached to netting and strung up in a greenhouse. It is advisable to spray the cocoons with water every day for the fortnight or so before the moths are expected to emerge, especially if they are kept in a dry atmosphere. This softens the cocoons and may help emergence. You can buy inexpensive hand sprays for the purpose.

Silkmoths, which have a rudimentary proboscis or tongue in consequence, do not feed during their brief adult lives. Under favourable conditions, mating and egg laying occur within two or three days after they emerge from the pupa, after which they soon die. An unpaired female may live for two or three weeks and spend most of that time motionless, apart, perhaps, from laying clusters of infertile eggs. Male silkmoths tend to be more active and are very short-lived. A virgin female silkmoth emits a scent from the rear part of her body which can attract males over a considerable distance. A similar faculty is found in some British moths and butterflies, for example, the eggar moths. A male detects the scent by means of his antennae, which are often elaborately feathered structures. A comparison of the antennae of different individuals is sometimes the simplest method of identifying the sexes. Females usually have thread-like antennae lacking the plumes of the male.

NOTES ON SOME EASILY REARED SILKMOTHS

The Indian moon moth (Actias selene)

Eggs of this fine species can be obtained in October and May, since it is usual for two generations to be reared in one year. The larvae will feed on rhododendron, plum, or hawthorn leaves. The preference for rhododendron is particularly useful to the rearer since there is no difficulty in obtaining leaves during the late autumn and winter for the second brood of larvae. During their early stages the caterpillars have red bodies with black warts or tubercles (plate 10). After the second moult the larva takes on a beautiful apple green colour and the tubercles become yellow or orange (plate 10). The larvae are voracious eaters and produce copious quantities of large, dry droppings. When fully grown, a caterpillar may be three to four inches long and as thick as a man's index finger (plate 11). The silken cocoon is spun among leaves or attached to the side of the

TABLE 1 Data on some British moths

Species	When to order eggs	Eggs laid	Eggs hatch	Chief food plants for larvae
Lackey (*Malacosoma neustria*)	January	July-August	April	Fruit trees, hawthorn, hazel, birch, oak
Kentish glory (*Endromis versicolora*)	January	April	May	Birch, hazel, alder, lime, sallow
Large thorn (*Ennomos autumnaria*)	June	September-October	May	Birch, alder, hawthorn, oak, poplar, sycamore
Lime hawk (*Mimas tiliae*)	January	May-June	June-July	Lime, elm, birch, alder, hazel
Poplar hawk (*Laothoe populi*)	January	May-June	June-July	Poplars, willows
Peppered moth (*Biston betularia*)	January	May-June	July	Sallow, oak, birch, elm
Puss moth (*Cerura vinula*)	January	May-June	July	Poplar, willows, sallow
Magpie (currant) moth (*Abraxas grossulariata*)	June	July-August	August-September	Currant, gooseberry, plum, sallow
Garden tiger (*Arctia caja*)	June	July-September	August-October	Dandelion, dock, privet, hazel

Pupation place	**Pupation month**	**Emergence**	**Other features of interest**
Leaves	June	July	Attractive larva, easy to rear, gregarious when young, spinning a web over leaves. Eventually solitary.
Leaf litter	July	March-April	Larva black at first, later green, attractive. Cocoon coarsely netted. Not common. Obtain from dealers only.
Food plant	July	September	Larva twig-like, a rare species. Obtain from dealers only.
Underground, often in leaf litter	September	May-June	Larva grows to a large size. Adults readily sexed, do not feed.
Underground	August-September	May-June	Larva grows to a large size. The commonest hawk moth. Adult emerges at night or in early morning.
Underground	September	May	Larva twig-like. Dark coloured (melanic) variety becoming common in urban areas.
Attached to tree bark	September	May	Larva brightly coloured, grotesque shape. Pupa enclosed in a hard, woody cocoon cemented to tree.
Anywhere—leaf, window sill	June	July	Larva attractively coloured, but sometimes a pest in gardens.
Leaf litter	June	July-August	Larva the familiar 'woolly bear', hibernates over winter, completes growth in spring and summer.

TABLE 2 Data on some British butterflies

Species	When to order eggs	Eggs laid	Eggs hatch	Chief food plants for larvae
Speckled wood (*Pararge aegeria*)	January or June	April and August	Within ten days	Coarse grasses, e.g. cocksfoot and couch
Green-veined white (*Pieris napi*)	January	May and July	Within 7 days	Cruciferous plants, e.g. garlic, mustard, watercress, horse-radish, lady's smock
Small tortoiseshell (*Aglais urticae*)	January (larvae)	May and July	June and August	Stinging nettle
Swallow-tail (*Papilio machaon*)	January	May-June and August	May and September	Fennel, carrot, angelica, milk parsley
Small copper (*Lycaena phlaeas*)	January	May to August	May to August	Sorrel, dock, ragwort

Pupation place	Pupation month	Emergence month	Other features of interest
On food plant	June and October	April and August	Eggs laid singly, double or triple brooded. Easy to breed.
On food plant or in leaf-litter	June, July, August	April, June, August	Eggs often hatch in less than a week after laying. Rapid life history with up to four broods per season. Pupa overwinters.
On nettles and in leaf-litter	June and August	June and August	Eggs laid in tight clusters which are difficult to separate, thus not sold. Larvae colonial web-spinners until final stage, Double brooded, adult hibernates.
On food plant	October	May	Eggs laid singly, larvae black at first with white saddle, later vivid green with orange and black bands. Attractive. A forked, orange tubercle, concealed behind the head, is protruded when larva is irritated. Very rare: obtain only from dealers, usually imported species.
On food plant	April	May	Eggs laid singly, larvae only 5/8 in long when fully grown. Triple brooded, easy to breed. Larva overwinters.

TABLE 3 Data on some tropical silkmoths

Species	When to order eggs	Eggs laid	Eggs hatch	Chief food plants for larvae
Ailanthus moth (*Philosamia cynthia*)	January	April-May	April-May	Privet, lilac, plum, ailanthus
Indian moon moth (*Actias selene*)	January and June	May and October	3 weeks after laying	Hawthorn, plum, rhododendron
Chinese oak (Assam) silkmoth (*Antheraea pernyi*)	January	April-May	May-June	Oak, birch, apple, hawthorn
Owl moth (*Brahmaea japonica*)	January	October	April	Privet, lilac
Squeaking silkmoth (*Rhodinia fugax*)	January	September-October	April-May	Oak, elm, hazel, sycamore, willow

Pupation place	Pupation month	Emergence month	Other features of interest
Hangs on food plant	June-July	July-August	From Europe, Asia, and America. One of the easiest species to rear. Some varieties (e.g. *P. cynthia ricini*) can be bred continuously under warm conditions. Pupal stage short, therefore popular in school.
Spins cocoon among leaves of food plant	July-August	August-September	From India. During development, larvae change from red to green colour. Can be bred continuously in warm room, but pupae formed in autumn hibernate under cool conditions.
Among leaves of food plant	August-September	April	From Asia. An easy species to rear and breed. Pupae overwinter.
On the ground	July-August	September-October	From Japan. One of the few silkmoths not to spin a proper cocoon. When larvae are about to pupate, put 1 in. of peat at bottom of cage and cover with glass supported on stones so that it is about ½ in. above peat. Cover glass with corrugated paper, stand food plant on top. Larvae crawl under glass. Eggs overwinter.
Attached to food plant	July-August	September-October	From Japan. Larva or pupa produces a loud chirping sound when disturbed.

S.C.E.R.T., West Bengal
Library
Calcutta
25/3, B. C. Road

container (plate 12). If the caterpillar pupates in the summer it will develop into an adult in a few weeks. Individuals of a second brood which pupates in the autumn do not emerge until the spring, although emergence can be hastened by keeping the cocoons in a warm place. Mid-morning is the usual time for emergence. It takes several hours for the wings to expand to their full size of about five inches. The moths are very beautiful (plate 13), and mate readily. Pairing usually occurs at night and the eggs are laid within a few days.

The Chinese oak silkmoth (Antheraea pernyi)

This species, sometimes called the Assam silkmoth, is one of the easiest of all to rear. Eggs can be obtained during the summer months from about the end of June onwards. The larvae feed on leaves of oak, evergreen (holm) oak, apple, or hawthorn. If evergreen oak is available, it is worth while attempting to rear an autumn brood from eggs laid in September or October. The newly hatched caterpillars have black bodies and brownish heads. After the first moult, the body colour changes to green. The fully grown larva spins a cocoon attached to either a twig or the side of the container. Caterpillars pupating in July and August will probably become adult in the autumn. Later formed pupae remain quiescent during the winter months. The adults pair readily.

The Japanese oak silkmoth (Antheraea yamamai)

This species winters in the egg state, and the caterpillars hatch out during April and May, feeding on oak or hawthorn leaves. At first, the body is yellow with black stripes along its length. Later, it turns green with silver spots and, eventually, tufts of yellow hair (plate 14). The oval cocoon, too, is pale green at first. Adult moths emerge in the autumn and, after mating, lay eggs which remain dormant until spring. Pairing occurs less readily than with the other species described.

The ailanthus moth (Philosamia cynthia ricini)

This species is easy to rear and will produce several generations in a year under warm, humid conditions. Eggs may therefore be obtained at all seasons and the larvae can be reared on privet or lilac. The first-stage caterpillars are yellow with black spots. During the later stages of growth the body colour is white, due to a waxy powder produced on the skin surface (plate 15). The cocoon is a papery structure attached by a long stalk to a twig. Adults pair very easily, usually at dusk (plate 16).

Suppliers of silkmoth eggs and equipment for rearing insects:

Worldwide Butterflies Ltd., Compton, Sherborne, Dorset.
The Butterfly Farm, Ltd., Bilsington, Ashford, Kent.

Stick insects

FEATURES

Stick insects, though not native to this country (they are tropical), are commonly reared in captivity and may be bought from dealers. The species generally supplied is the Indian stick insect, *Carausius morosus*. This thrives at room temperature and feeds on privet, ivy, or hazel. It is an interesting example of protective resemblance, with the thin body, long spindly legs, and brown colour giving it the appearance of the twig of the plant it rests and feeds on. It is most active during the night, but sometimes feeds during the day as well. For most of the day, however, the adult stick insect is motionless with its limbs and antennae extended in line with the body in a stick-like attitude (hence its name). It will 'freeze' into this attitude if disturbed in action.

LIFE CYCLE

Male stick insects are very rare, and females lay fertile eggs without mating, a phenomenon known as parthenogenesis. The dark brown, oval eggs are about 3 mm long, very hard, and strikingly like seeds, and have a lid at one end through which the nymph emerges on hatching. It is generally assumed that stick insect eggs take anything from four months to a year to hatch, but there have been reports of eggs hatching under normal classroom conditions in less than a month.

Newly hatched nymphs (figure 44) will drink water immediately, but do not feed for some time. Thereafter they eat chiefly in the evening and morning and do not drink again until towards the end of life. Nymphs moult six times before reaching adult size (without a pupal stage—incomplete metamorphosis), on average a length of 80 mm. This takes about five months under normal classroom conditions.

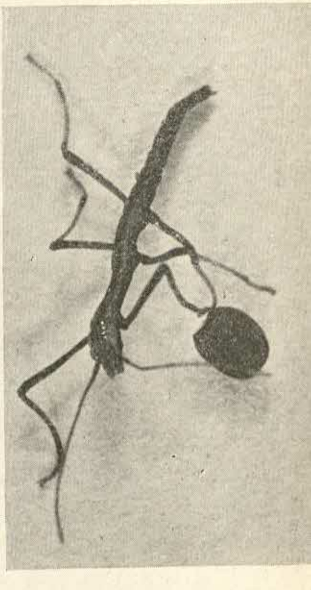


Fig. 44. A newly hatched stick insect.

REARING

Stick insects can be reared in plastic lunch boxes or more elaborate insect cages. Eggs should be kept in plastic pill boxes at room temperature until they hatch.

Locusts

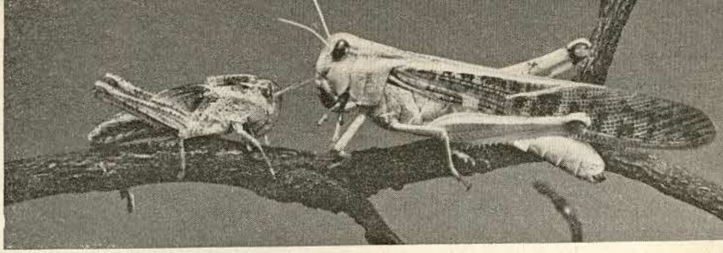
FEATURES

Strangely enough, the locust, which is not native to this country, is very easily reared in schools. The Anti-Locust Centre, however, advises against keeping locusts in the classroom as they have been known to produce allergies. It is best to keep them in a corridor, laboratory, or any other part of a school building which is not constantly in use by the *same* children.

These insects will accept as food an amazing variety of plant material including almost any kind of leaf, root vegetables, seeds, bran, and cereal products. There is never any problem in supplying food to a locust colony. They are gregarious insects and large numbers may be kept in one cage. The adults are large enough to be handled easily. The various parts of the insect may be examined without recourse to a hand lens. With a colony of locusts one is certain to witness the phenomena of moulting, mating, and egg-laying many times. The only 'special' requirement is a heated cage, but the source of heat need be nothing more complex than an electric light bulb. Locusts may be kept in any kind of container: a biscuit tin with a glass top placed near a radiator is quite satisfactory. The Perspex cylinder cage described on page 172 is also suitable for locusts. A home-made general purpose cage, adapted for locusts, is illustrated in figure 46. The optimum temperatures for growth and reproduction of locusts are 28-34°C, the higher being the ideal daytime temperature in the cage. At normal room temperatures growth occurs more slowly. There are many kinds of locust, but two species are easy to obtain from dealers and both are suitable for rearing in schools. These are the African migratory locust (*Locusta migratoria*—see figure 45) and the desert locust (*Schistocerca gregaria*).

Locusts, of course, are insects of great economic significance. The desert locust is potentially the world's most expensive pest to agricultural crops. It was estimated in 1961 that the annual cost of control measures taken against the desert locust amounted to more than four million pounds. Damage done by the locusts may cost four times as much. Swarms of desert locusts invaded French

Fig. 45. An adult and a nymph of the migratory locust.



Morocco during 1954 and within six weeks caused damage to cultivated crops amounting to four and a half million pounds. Only an army can equal the destructive force of a locust swarm. One of medium size may contain a thousand million individuals and consume three thousand tons of food daily. More than sixty countries in Africa and Asia are liable to attack by locusts. Little wonder that full-scale international cooperation has been necessary to contain these attacks.

Although the African migratory locust has been kept under control for over twenty years, its larger relative, the desert locust, is still a major threat to the economies of Africa and Asia. Indeed, the desert locust menace has increased in recent years as drier, semi-desert areas favoured by this species have come under the plough.

Effective control of the migratory locust became feasible when research into the habits of the insect revealed that plagues originated in only a few localities. Strict watch is kept on these areas which are sprayed at the first signs of an outbreak of locusts. Desert locusts breed in many scattered localities and this makes control much more difficult. Weather conditions are an important factor affecting the development of locust swarms. When winds concentrate scattered locusts into an area that has had recent heavy rainfall the conditions are ideal for an explosion of the locust population.

LIFE CYCLE

An adult female lays batches of 50-100 eggs in damp sand. These are surrounded by a white frothy secretion which hardens in contact with air. Under favourable conditions the eggs hatch in about two weeks and the young stages, called nymphs, wriggle to the surface of the sand and undergo a moult almost immediately. The nymph (figure 45) or 'hopper' is like a small grasshopper. It feeds on any available vegetation and grows by shedding its skin five times until the winged adult form is assumed. There is no pupal stage so the locust is an example of an insect having incomplete metamorphosis. If the hoppers are crowded during their development, as usually happens when there is severe competition for food, they become very active and may 'march' in large numbers, moving in one direction up to several miles from the hatching ground. After the final moult to the winged condition, the swarm of locusts takes wing for daily flights which eventually become prolonged migrations of hundreds of miles.

If the hoppers are not crowded during development they remain relatively inactive, do not march, and when adult do not swarm. In addition, all stages are paler in colour, often being green. At one time these solitary green 'grasshoppers' were thought to be a separate species from the darker-coloured gregarious forms.

REARING LOCUSTS

The general purpose cage in figure 46 may be used to house locusts. This cage has a perforated zinc false floor set four inches above the base of the cage. Beneath this is a 40 W bulb which heats the cage. Supplementary heat and light is provided by a 30 W strip light fitted to the roof of the cage. The best temperature for locust development is about 32°C. There will be a temperature gradient in the cage and the locusts will tend to move from those parts which are too hot or too cold. During cold weather it may be necessary to change the bulb for one of higher wattage. It is useful to have a thermometer in the cage to keep a check on temperature fluctuations. The strip light should be switched off in the evening since it seems to be beneficial for the locusts to have cooler conditions at night, presumably in imitation of the natural conditions.

Locusts will eat a wide variety of plant materials. Grass can be the staple diet, but in winter it may be more convenient to give Brussels sprouts, cabbage leaves, or even slices of raw potato. All seem to be grist to the locust mill.

Eggs are laid by the female in damp sand and provision must be made for this. Sand-filled tubes, plant pots, or jam jars are suitable containers. They should be at least four inches long since the female lays eggs at this depth, and not less than 1½ inches in diameter. Holes of appropriate size should be cut in the false floor and the sand-filled containers placed beneath so that the sand is flush with the floor of the cage. The sand should be moistened by adding 15 parts of water to 100 parts by volume of dry sand.

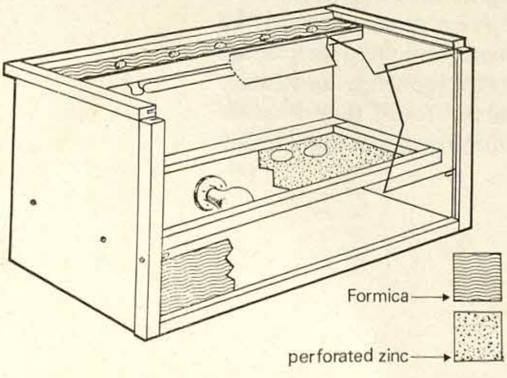


Fig. 46. A general purpose cage set up for rearing locusts.

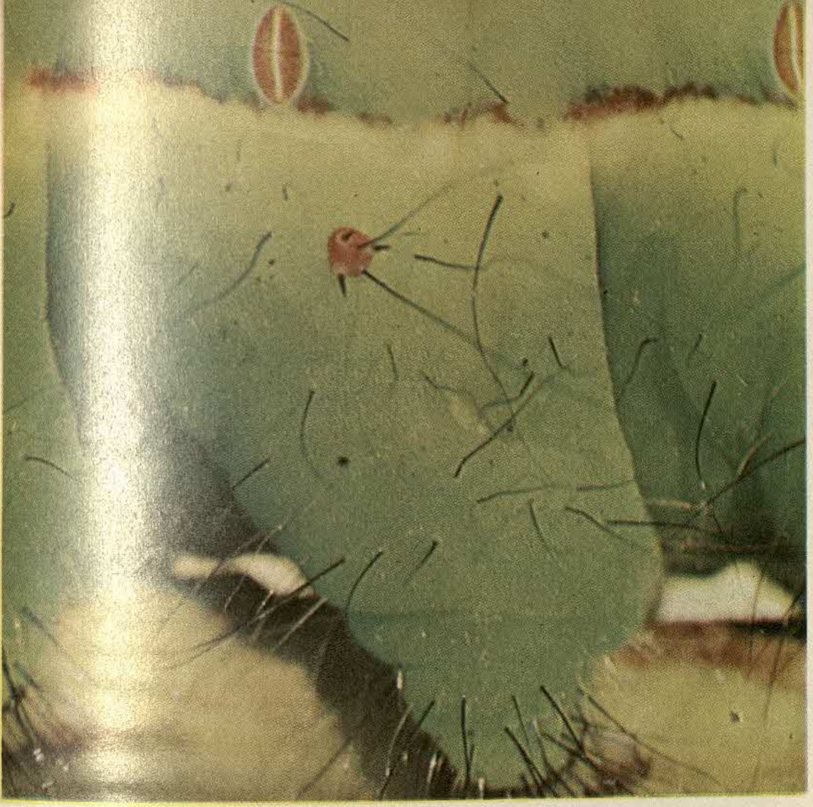
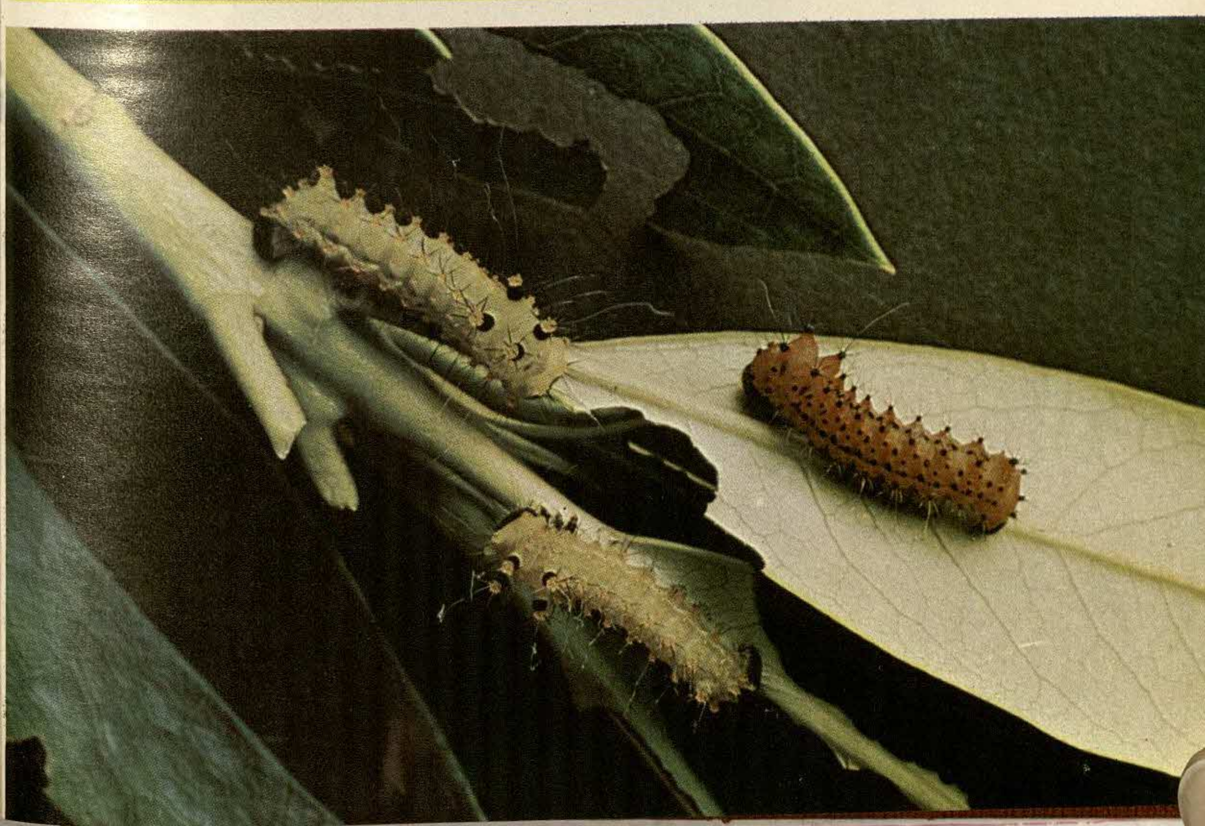


PLATE 9 (*left*). One segment of an Indian moon moth larva showing a spiracle, and part of another segment and spiracle. The spiracle opening is a white slit surrounded by an oval orange area.

PLATE 10 (*below*). Two stages of the Indian moon moth larva: the early stage (right), and after the second moult (left).



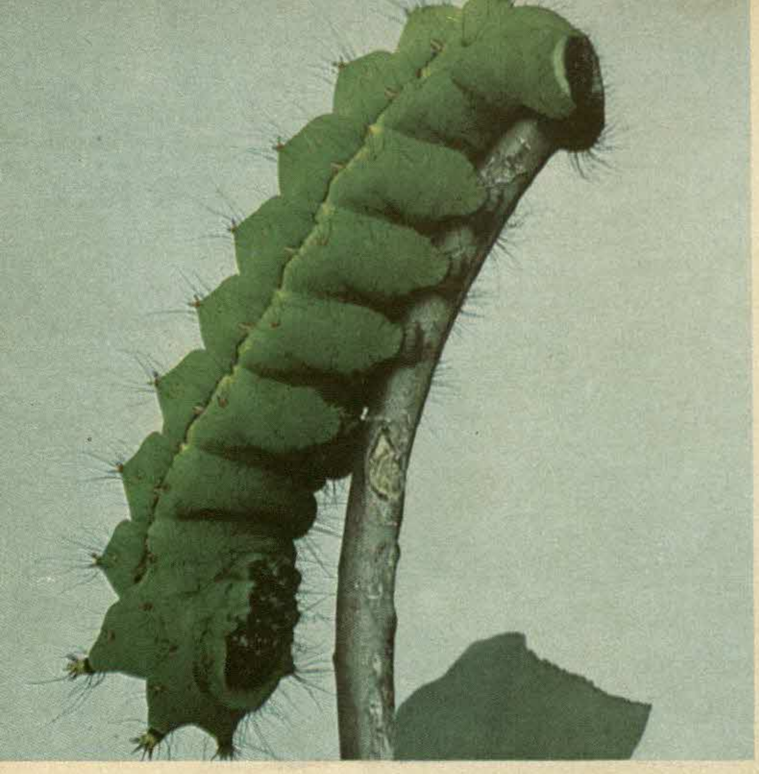
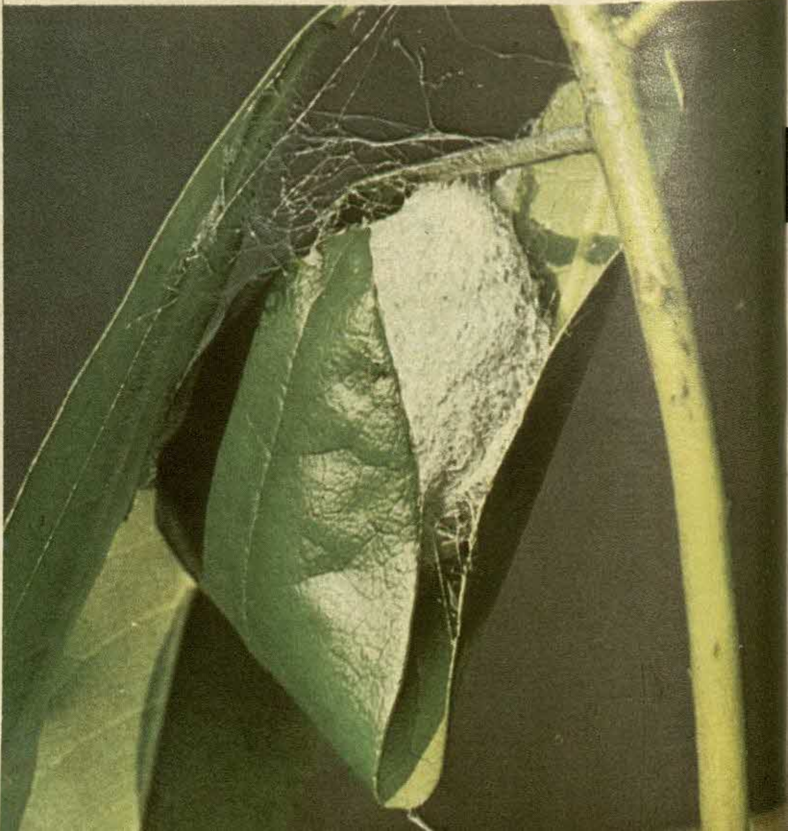


PLATE 11 (*left*). Indian moon moth larva in the fifth stage, with head in the characteristic down position.

PLATE 12 (*right*). Indian moon moth cocoon spun among rhododendron leaves.



It may be necessary to add a little more water from time to time, to prevent the sand from drying out. Alternatively, the tubes may be replaced with fresh ones. Eggs hatch within about fourteen days, depending on the temperature. Branching twigs should be placed in the cage so that the hoppers can climb up near to the strip light when they are moulting.

The African migratory locust is the easiest species to rear and is the one generally supplied by dealers. The desert locust is perhaps a little more difficult and has a longer life cycle, but on the other hand it will eat a more varied diet.

INSTRUCTIONS FOR CONVERTING THE GENERAL PURPOSE CAGE INTO A LOCUST CAGE*

Materials

Two pieces of 24 oz gauge glass measuring $18\frac{7}{8}$ x 7 in. and $18\frac{7}{8}$ x 6 in.
One piece of perforated zinc measuring $17\frac{1}{2}$ x $7\frac{3}{4}$ in. fixed to a wooden frame measuring $17\frac{7}{8}$ x 8 in.
5 ft of $\frac{7}{8}$ in. sq deal for the frame
One piece of Formica measuring $18\frac{7}{8}$ x 4 in. (aluminium sheet is also suitable)
One 40 W lamp and holder
One strip lamp unit as described for the reptile cage (page 109).
Four $\frac{1}{2}$ in. 2 B.A. nuts and bolts, and two 1 in. 4 B.A. bolts

Make a rectangular frame out of $\frac{7}{8}$ in. square deal to slide into the cage, forming a false floor. Perforated zinc is tacked to the frame. Two holes should be cut in the perforated zinc of the same size as the egg-laying tubes.

Four holes are drilled in the sides of the cage, 4 in. above the base of the cage. Fix nuts and bolts into the holes so that the nuts project into the cage and provide support for the false floor.

Two further holes are drilled in the wooden side pieces at the front of the cage, also 4 in. above the base. These take two 4 B.A. bolts which support the glass front.

The Formica is inserted into the grooves below the glass front to reduce heat loss.

A bulb holder should be fixed, either to the back of the cage below the false floor, or to the Formica at the front of the cage.

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* Note that cages made to the specifications of the Anti-Locust Centre are available commercially from suppliers of scientific equipment.

Mealworms (*Tenebrio sp.*)

The mealworm is the larva of the beetle, *Tenebrio molitor*. In Britain it is found as a pest of stored cereal products, but its natural habitat is the desert. Both adults and larvae are much used as food for amphibia, reptiles, and cage birds. Many dealers sell mealworms and, although expensive, they are an important form of insect food, readily available at any time of year. The mealworm is also a very suitable insect to keep and study as an example of a beetle. All stages of the life cycle are readily obtained in a classroom culture.

LIFE CYCLE

One usually starts with mealworm larvae bought from a dealer. These feed on bran and small pieces of fresh vegetable. The larvae moult several times and eventually grow to a length of about one inch. They then shed the skin once more and change to pupae. These are white, at first, but gradually change to a light brown colour. The pupae do not feed and their movements are limited to a few wiggles. If crumpled newspaper is placed on the food, some larvae pupate in this. Perhaps the larvae seek drier conditions for pupation.

Eventually the adult beetles emerge, breaking out of the pupal skin. The adult is at first a whitish beetle measuring about ¾ inch in length. Within two or three days, as the cuticle hardens, its colour changes to a chestnut brown. Later the beetle darkens still more, so that it is finally black. The adults feed on cereal products. The sexes are difficult to distinguish. We have not found any external differences. This does not seem to be of practical importance because, presumably, in a colony of say twenty beetles or more, both sexes are virtually certain to be present. We have not witnessed mating, but the females, doubtless after mating, lay eggs in the food, and the cycle is repeated.

The duration of each stage in the life cycle depends on the environmental conditions. At a temperature of 30°C the average duration of each stage is:

egg—10 days,
larva—10 weeks,
pupa—20 days,
adult—10-20 days.

Thus the complete life cycle takes about four months.

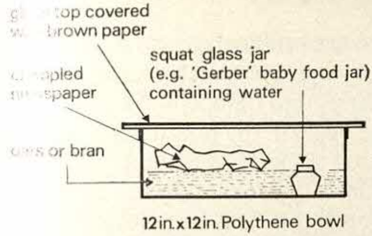


Fig. 47 (a). A mealworm culture in a Polythene bowl.

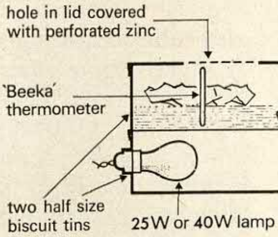


Fig. 47 (b). Rearing mealworms in a biscuit tin. Heat is supplied by a lamp.

REARING

It is not so simple to culture mealworms on a large scale. The life cycle takes about four months at 30°C, and longer at lower or higher temperatures. Therefore several cultures at different stages are required to yield a continuous supply of mealworms. As a rough guide, six boxes of half biscuit-tin size would probably supply a pair of green lizards continuously. Of course, if the diet is supplemented with other food, such as earthworms and flies, a correspondingly larger number of reptiles can be kept supplied. In any case this is normal practice since a varied diet keeps reptiles in good condition.

The mealworm can survive very dry conditions, but its growth is accelerated when the air is humid. The conditions necessary for running a successful culture can be summarized quite simply, as air, warmth, high humidity, and abundant food.

Polythene washing-up bowls, about 12 in. square, are very good for mealworm cultures since they are easy to clean, and do not rust. In addition, the sides of a bowl are so smooth that the mealworm cannot climb out of the bowl. Half-size biscuit tins are about half the price of a washing-up bowl, but rust quickly, especially if kept out-of-doors. (See figure 47.)

To set up a culture, pour porridge oats into each bowl or tin to a depth of 1 in. About 1 lb of oats is required for a 12 in. square bowl. This is the food material for both mealworm beetles and the larvae. Bran, chick starter mash, and cereal products are satisfactory alternatives. About 1 oz of mealworm larvae is needed to establish a colony in each box.

There are several possible methods of raising the humidity in the culture box. The simplest is to dampen the food with tap water. However this encourages the growth of moulds and other fungi and also compacts the oats so that it becomes difficult to extract larvae. A slightly more effective method is to place slices of freshly cut potato on top of the oats. The moist potato dampens the food, but only locally. Mealworms congregate beneath the potato and burrow into it. A small part of the cereal food sticks to the potato, but this is not inconvenient. Some authorities suggest that fresh vegetables stimulate the adult beetles to lay more eggs. It is not clear whether this is due to the water contained in the food or perhaps to some vitamin.

In our experience, the best way to increase the humidity without stimulating mould growth is to have a glass jar half full of water in the culture vessel and keep a lid over the whole culture (figure [illegible]). The jar must be short and squat so that it is not easily overturned. So far as we can tell, the mealworms do not seem to suffer from a lack of oxygen or an excess of carbon dioxide. The cultures are examined with the minimum of disturbance, about once a week. Perhaps this is sufficient to ventilate the boxes.

Houseflies and blowflies

FEATURES

The houseflies and blowflies are all too common in our houses and most of us do all we can to discourage them. Our dislike of these insects is well founded since they are confirmed carriers of disease. What happens is that the fly, attracted by the smell issuing from decaying organic matter such as dung, kitchen waste, or compost heaps, feeds on these materials and in so doing, may pick up bacteria. If the fly subsequently alights on food, the bacteria may be transferred and may multiply, causing the food to decay rapidly. Flies also have the interesting, though to some people, repulsive habit of squirting digestive juice over the food so that it dissolves. This is very necessary to the fly because its mouth parts are modified in such a way that only liquid food can be taken in.

The term 'fly' which we apply rather indiscriminately refers to an enormous group of insects that have in common the possession of one pair of wings instead of the more usual two pairs. The second pair of wings in flies is reduced to minute drumstick-shaped outgrowths from the thorax which have become modified to function as organs of balance. They are called halteres. Flies are aptly called *Diptera* (two-winged) and, apart from our houseflies and blowflies, the group includes some of the most highly specialized and successful insects such as mosquitoes, tsetse flies, midges, and horseflies.

LIFE CYCLE OF HOUSEFLIES AND BLOWFLIES

The adult female, after mating, lays eggs on or near to food suitable for the larvae. Generally speaking, houseflies choose both decaying animal and vegetable matter for egg laying, while blowflies are slightly more selective with a preference for meat or fish. The eggs are elongated, cylindrical and laid in batches of up to 60. They hatch out, sometimes within 24 hours under warm conditions, and the larvae burrow into the food.

Fly larvae are usually called maggots. They are well suited to a burrowing habit, being pointed at the front and lacking any major interruptions of the smoothly tapered form. They are legless and blind though still sensitive to light since they constantly move away from light into shady places. The larvae feed on whatever food is available, and, under favourable conditions, grow rapidly, moulting several times before changing into a cigar-shaped pupa. This is covered with a layer of cuticle, white at first, but gradually darkening through brown to black. This outermost protective layer of the fly pupa does not correspond with the pupal case of a butterfly or moth. It is actually the skin of the last larval stage retained over the live pupa. The combined structure of pupa plus the sheath of larval skin is called the puparium (figure 48).

Within the pupa the larval tissues disintegrate and adult structures develop, using the 'raw' materials from larval tissue. It is incredible that from the legless, eyeless, virtually headless maggot, within ten days or so there develops a winged insect with six legs, large compound eyes, and a highly organized sensory system. But that is what happens. The fully formed fly breaks out of the puparium, in the process, incidentally, using a very neat hydraulically operated 'can opener', and crawls towards light. Its wings soon expand and the cuticle covering the body hardens and assumes the characteristic, often attractive, sheen of the adult. After a short period of grooming the adult fly takes to the wing and recommences the cycle of events which will produce another generation to harass the housewife.

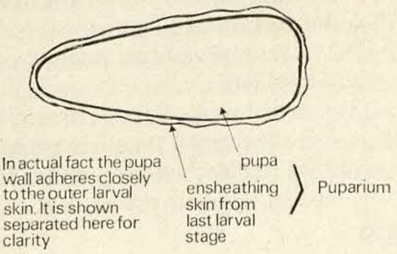

In actual fact the pupa wall adheres closely to the outer larval skin. It is shown separated here for clarity
pupa
ensheathing skin from last larval stage
Puparium

Fig. 48. Longitudinal section of a fly puparium.

REARING FLIES

When reared in captivity, flies are not potentially dangerous disease carriers and teachers need have no fears on this score. We recommend the rearing of flies, particularly if there are amphibia or reptiles to be fed, since they are easily cultured and a much-favoured food. The method we use is simple and less obnoxious than many. However it is best carried on out of doors because inevitably there are odours produced by the decaying food.

Rearing blowflies and houseflies

It is not difficult to rear the larvae of blowflies and houseflies, particularly during the summer months, when the operation can be carried on out of doors. The method described has the advantage of keeping smells down to the minimum. The housefly has a life cycle of 2-3 weeks, and the blowfly 3-4 weeks, so supplies of insect food for amphibia and reptiles can be obtained quite quickly.

Place a layer, about 1 in. thick, of canned dog meat such as Chum in a jam jar. A small tin contains enough for three jars. Leave the jars in the open air. Flies of various kinds will lay eggs on the meat. When 50-100 eggs have been laid in a jar, cover with a muslin top or perforated lid to prevent further laying. This is necessary, otherwise too many larvae will be competing for the food.

When the larvae are $\frac{1}{2}$-$\frac{3}{4}$ in. long fill up the jar with sawdust to an inch from the top. Re-cover with muslin. The larvae leave the meat and pupate in the sawdust. If the flies are bred as food for reptiles, the sawdust containing larvae and pupae should be shaken into a shallow container and this transferred to the vivarium. Lizards and other reptiles feed on the larvae and on newly emerged adults. Any large holes in the vivarium should be stopped up so that the flies do not escape.

The advantages of this method of culture are:

(*a*) Simplicity

(*b*) Canned meat contains preservative and therefore decays slowly, with less smell than fresh meat

(*c*) One avoids handling either larvae or flies; this in itself is a useful hygienic precaution.

Bees

Ants and bees are equally industrious social insects with an apparently selfless regard for the welfare of the colony. Not only is their tireless effort an inspiration but their division of labour ensures a community of high efficiency. With these exemplary qualities, a colony of bees would be an asset to any school but its chief value is found by the teacher who wants to base class work on the observations, questions, and activities of children. A hive of bees so stimulates curiosity and imagination that opportunities abound for studies involving language and number.

GENERAL FEATURES

The hive bee, *Apis mellifera*, is cultivated in many parts of the world for the honey it produces. The bee is a social insect which exists in colonies or hives containing as many as 100,000 individuals. Within this functional unit there is a remarkable division of labour. This has the effect of increasing both the numbers of bees produced and the amount of honey stored in the hive. There are three castes or types of bee with distinctive structural features: first the queen, a single individual who is a fully fertile female with an apparatus for egg laying and stinging; secondly there are the numerous workers who are sterile females with an apparatus for stinging only; thirdly there are drones in small numbers, most abundant in the spring. These last are fully fertile males with an apparatus for the insemination of females. The queen and the workers develop from fertilized eggs and the drones from unfertilized eggs.

LIFE IN THE HIVE

The queen bee can, for short periods, lay an egg every 10 seconds, and a total of 1,500 eggs laid per day is not unusual. She has a long, fat abdomen owing to her ovaries which are very large in proportion to the other organs. The queen is constantly attended by workers who give her huge amounts of food, produced from their specially modified salivary glands, the so-called brood-food glands. The reason that the workers are so attracted to the queen is their craving for a substance, queen substance, which exudes from the queen's skin. The workers nearest to the queen touch her with their mouthparts, take up small amounts of queen substance (as those near her tail, in figure 49, are doing), and feed several other bees in quick succession. In this way all the bees inside the hive receive queen substance.

Most of the eggs laid by the queen are deposited by her in hexagonal cells made from wax by the workers. The eggs in these cells develop into more worker bees and increase the population of the hive.

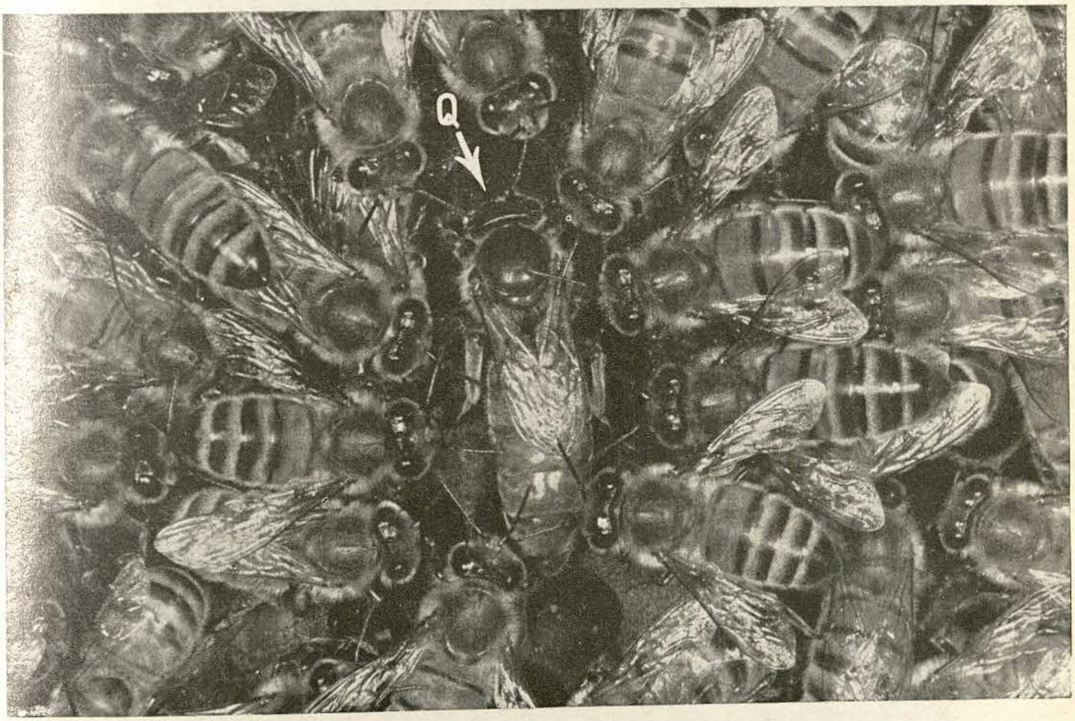
The groups of hexagonal wax cells are called comb. In a wild hive certain regions of the comb are used for egg-laying, called brood comb; others, used for pollen storage, are called storage comb; and others, used for honey storage, are called honeycomb. The beekeeper who wishes to keep broodcomb and honeycomb separate inserts a queen excluder in his hives. This is a perforated sheet which has holes too small for the queen to pass through.

The worker bees hatch out from the broodcomb cells, grow, moult several times, pupate, and eventually emerge (figure 50). The larva is a white coloured, maggot-like creature with reduced legs. It eats the food provided by adult workers—at first the liquid called royal jelly, which is actually produced from the brood-food glands of the workers, and later a mixture of pollen and honey. A cap of wax is placed over the cell containing a larva shortly before it pupates. It usually takes about three weeks from the time the egg is laid to the emergence of the adult worker.

The newly emerged worker bee carries out domestic chores inside the hive for about a fortnight after emergence. These tasks include cleaning and repairing cells, fetching and carrying pollen and honey from other parts of the hive, feeding the queen on demand, sealing up cells containing maturing larvae, and fanning with the wings to create a draught in the hive. The wing fanning progresses into guarding the front door. The worker stings to death any intruders, including bees from another hive. Then the worker makes its first flight, of a few feet, outside the hive. The flights become successively longer and the bee learns the topography of the neighbourhood. The worker eventually makes journeys to collect nectar or pollen. These collecting trips are made according to information given to the foraging workers by scout workers who go out shortly after dawn and return to the hive to perform a directional dance on the comb which indicates the direction and distance from the hive of nectar or pollen. A few of the worker bees eventually progress to become scout bees and perform this highly organized and useful task of locating rich sources of honey and pollen. The worker bee seldom lives for more than 6 weeks.

There are never more than a few hundred drones in the hive. They are large with magnificent wings. Drones develop from unfertilized eggs laid by the queen in drone cells which are larger than the worker cells. The drones do none of the many chores carried

Fig. 49. Part of the colony of *Apis mellifera* showing queen and workers. Photo, C. G. Butler.



out by the worker bees, but they have a vitally important function, namely to fertilize a new queen.

During the early summer months when the population of the hive is growing rapidly the workers make a few cells which are different from drone or worker cells. They are much larger, acorn shaped structures which hang downwards from the comb. They are open at the base. These are queen cells and the larvae in them are given large amounts of royal jelly for the whole of their larval lives, and not just for three days as in the case of worker or drone larvae. Consequently these larvae grow rapidly to a much larger size and develop into potential queens. Usually one emerges before the others and makes a small hole in any other queen cells she finds. Workers destroy these damaged queen cells with the result that any potential rival queens are killed.

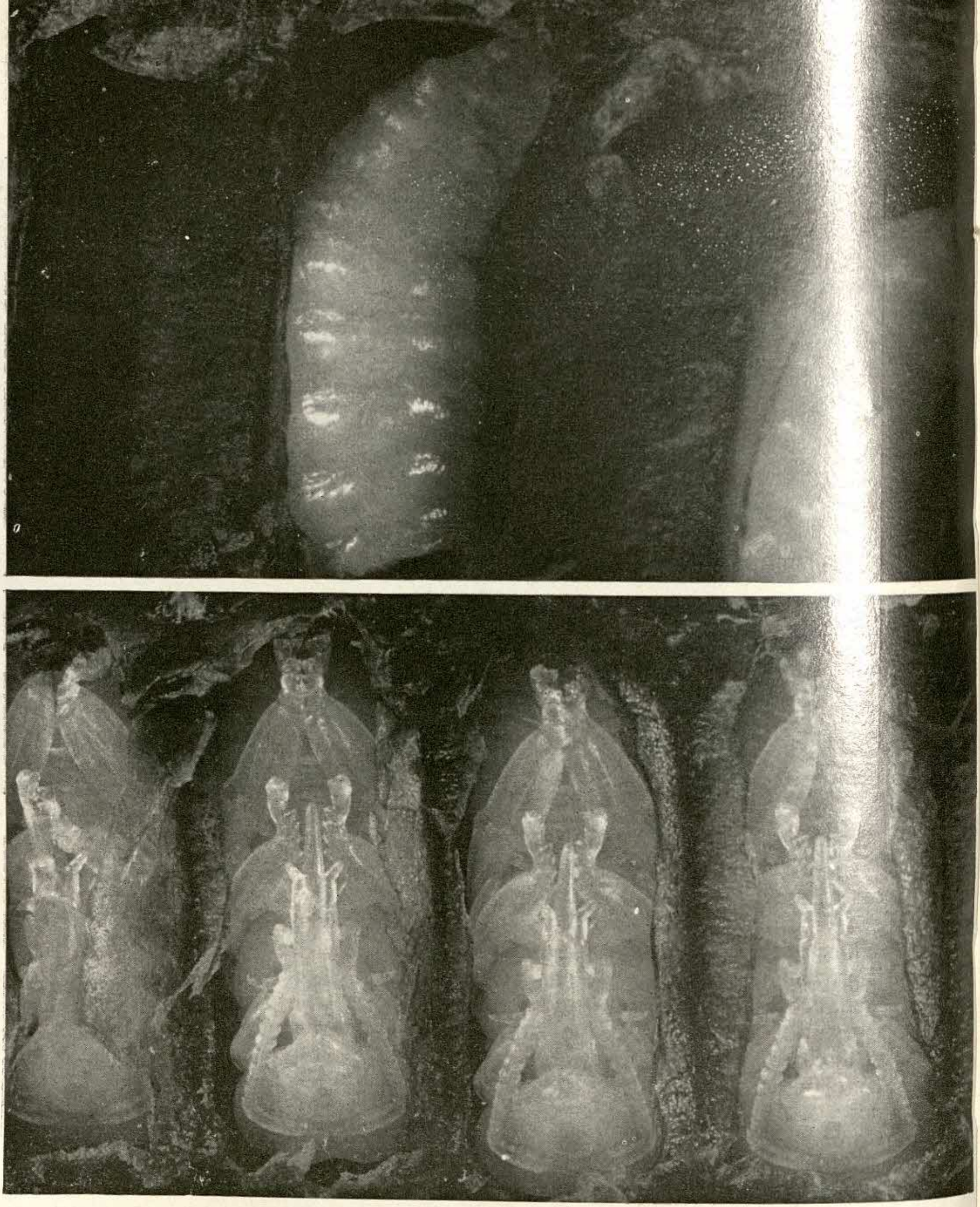


Fig. 50. *Apis mellifera:* (*above*) A full-grown larva in a cell, and (*below*) pupae in their cells. Photo, C. G. Butler.

A newly emerged queen leaves the hive, usually alone, but sometimes followed by drones. This is called the nuptial flight but some of its details are still obscure. Possibly drones from several hives assemble in definite places to which virgin queens are attracted, presumably by an odour given off by the drones. Mating might occur either on the wing or on the ground. The union between a drone and the queen is so intricate that the drone's body is invariably torn when the pair separate after mating and the drone quickly dies. A queen may mate with several drones in succession and the sperms she receives and stores are sufficient for all the fertile eggs she subsequently lays.

The mated queen returns to the hive and is received with a good deal of interest by those bees who happen to be nearest to her. They fondle and feed her, and she acquires a retinue of bees which obtain queen substance from her. For a time the new queen and the old may live together in the hive, but eventually the old is superseded by the young queen.

Swarming is a well known characteristic of the hive bee, and it is linked with the production of new queens, when the colony is becoming crowded. Shortly before a new queen is due to emerge from a queen cell the established queen leaves the hive accompanied by many workers and a few drones. This swarm establishes itself in a new home located by scout bees which have been searching for sites several days prior to swarming. When a virgin emerges in the original hive she may also depart in a swarm or alternatively, remain in the hive and kill any other potential queens.

In the autumn the drones, which never forage for their food, are no longer fed by workers and they die of starvation. Some may be killed by workers. Their corpses are thrown out of the hive. As activity in the hive subsides due to lower temperatures and a shortage of nectar and pollen, the queen lays fewer and fewer eggs. She is surrounded by a tight cluster of workers and the temperature in the centre of the cluster seldom falls below 21 °C. This habit of clustering enables some of the bees in the colony to survive the winter as adults. Most insects that live in temperate zones survive winter as inactive eggs or pupae which seem better able to withstand cold.

BEE KEEPING IN SCHOOLS

Bee keeping should only be started by someone with a genuine interest in the craft, and neither staff nor children should be forced to participate in the management of hives.

For a beginner to stand beside a colony of 50,000 bees with the 'lid off' can be a frightening experience. Indeed it was the habit of one teacher, when an Inspector appeared, to seek refuge by opening up his most vicious colony! Adults show more fear than children. The apparently fearless approach of a class that worked stripped to the waist resulted in fewer stings than when veils, gloves, and other protective but clumsy clothing was worn. The pupils could see clearly and handle carefully. Clumsy manipulation, when hive parts are bumped, or jerky, sudden movements frighten bees so that they sting in defence. If hives are opened, after being adequately subdued with smoke, in calm, warm weather, with gentle, slow movements, stings rarely result. However, it is a wise precaution at all times to keep away from the entrance: bees hate to have their flight-lines obstructed.

A bee usually leaves the whole mechanism behind when it stings, and this should be scratched out with a fingernail not pulled out. When a child is stung, the best palliative is probably honey. The smell of a sting soon tells other bees that an enemy is at hand, so it is a wise precaution to send the child away at once, to save him from further stings.

It is in fact the practice of one teacher to apply a bee to the dorsal surface of his forearm so that each class may see the worst a bee can do. In this way children are conditioned to make light of the odd sting they may receive. Really severe results from stings are very rare, one on the tongue being the most dangerous.

How to begin

Before starting it is helpful to join the local bee keepers' association or contact the County Adviser on apiculture, who may be attached to the Education Authority. The County Advisers are usually helpful and can introduce a beginner to an apiary where he can observe a bee keeper at work. There is a great spirit of fellowship among those practising the craft. If, after this, the teacher still wants to keep bees, he will be wise to stimulate interest in the children so that they can be keen partners in the project. He can easily do this by taking them for a walk across any garden or city park to find where bumble bees are foraging. The children are fascinated, the imagination is fired, and a class of potential bee keepers results. One teacher achieved a similar success after each child had received a spoonful of honey. Once interest is roused, the possibility of keeping honey bees can be discussed and plans made.

Choice of site

Four bricks, carefully levelled from side to side but slightly sloping to the front, should be set out to receive the hive in a dry place, safe from disturbance, and facing the south-east. It should be away from a path, sheltered from the wind, but able to receive winter sunshine. Bees can survive cold, but succumb to damp.

What kind of hive? What race of bee?

One should be guided in choice of hive and strain of bee by the local experts who will have discovered over the years what gives the best results for that locality. However, a light, simple hive and a sweet-tempered strain are more important factors in school bee keeping than weight of harvest. The wealth of exciting educational possibilities flowing from the hive are all important. But it is nice, on sports day, to be able to provide home-produced honey for the parents' tea. (This, of course, is a cunning advertisement for the product!)

None of the various bee diseases is harmful to man but a diseased colony is unlikely to produce a harvest and it is an essential in bee keeping, as in other forms of livestock husbandry, to purchase sound stock from a reliable source: bargain colonies should be examined very carefully. Some keepers buy bees and hive together, others prefer to have the colony, which will be on frames, fitted into a new hive, while some buy a swarm and run it on to new frames in a hive.

If an old empty hive is bought, it should be well scraped inside and then scorched with a blowlamp to kill any disease spores. If funds permit, it is better to start with two colonies and here the hives should be identical so that parts are interchangeable.

Observation hives

The whole project is enriched by setting up a glass walled observation hive which brings greater understanding of bee biology, reveals the secrets of the bee city, and widens the scope for study and recording. They are an endless source of wonder to children and vary from small, single frame boxes, which are useful as a visual aid at a lecture, to many framed Perspex or glass windowed structures which can be studied over the whole year. If one big enough to carry three frames is fitted to a classroom window, it will have sufficient bees to maintain itself during the summer but syrup should be supplied in spring and autumn.

MIGRATORY BEE KEEPING

With the increased use of herbicides, the spread of large-scale barley growing, and the making of silage in preference to hay, clover as a source of nectar has vanished from many areas. It may be economically sound to move a hive for a period of weeks to take advantage of a flow of nectar, perhaps in a bean field or on a heather moor. In Australia there is a large nomadic population following the various forest flows, covering 1,000 miles in a season and producing 80 per cent of the exported honey.

SUGGESTED TOPICS

1. History of bee keeping: honey as the only sweetener before cane and beet sugar. Primitive man still hunts for wild bees' nests. Hollow tree hives, skeps, modern movable frame hive.
2. Study of honey from different flowers: sycamore, lime, apple, clover, heather, bean, orange (Spain), eucalyptus (Australia), acacia.
   Which way do our bees fly? Where do they go? What flowers are they working on? How do they collect the nectar and pollen?
3. Physiology: compare with ant, wasp, all 3-part body, 6 legs; insects.
   Functions of the legs—a built-in bag of tools. Antennae, eyes, communication through dance movement.
4. Life history of individual and colony. Compare with wasp, bumble bee.
5. Economic value. Pollination, production of honey (mead) and wax (cosmetics, chewing gum, polish, candles, crayons).
6. Find a bumble bee's nest and examine it. Do they visit the same flowers as honey bees?
7. Organization of hive. When do they start work? Does weather affect their work? How hot is it inside a hive? Ventilation. Soldiers.

MINIMUM EQUIPMENT

A smoker, feeder, bee escape board (to fit your hive), queen excluder hive tool, and some veils. Quilts to go on top of the bees but under the roof can be cut from old carpets or linen sheets.

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See also:

Ministry of Agriculture, Fisheries and Food Advisory Leaflets. H.M.S.O.

Publications of the Bee Research Association, Hill House, Chalfont St. Peter, Gerrards Cross, Bucks.

PERIODICALS

Bee Craft. (Apply to Mr. A. W. St. Clair, Secretary to the Bee Keepers' Association, 28 Weald View Road, Heathfield, Sussex.)

Bee World, published by the Bee Research Association (see above).

Scottish Bee Keeper, c/o Mr. Andrew Smith, 1 Kenilworth Avenue, Foxbar, Paisley.

PLATE 13 (*right*). The adult Indian moon moth.

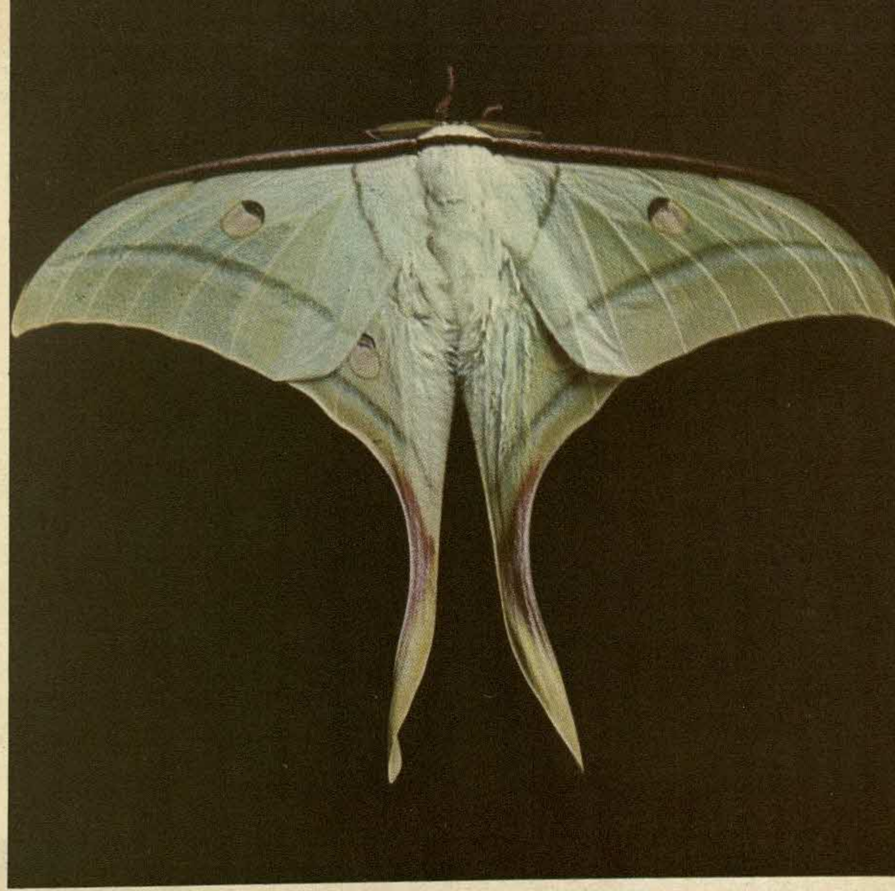
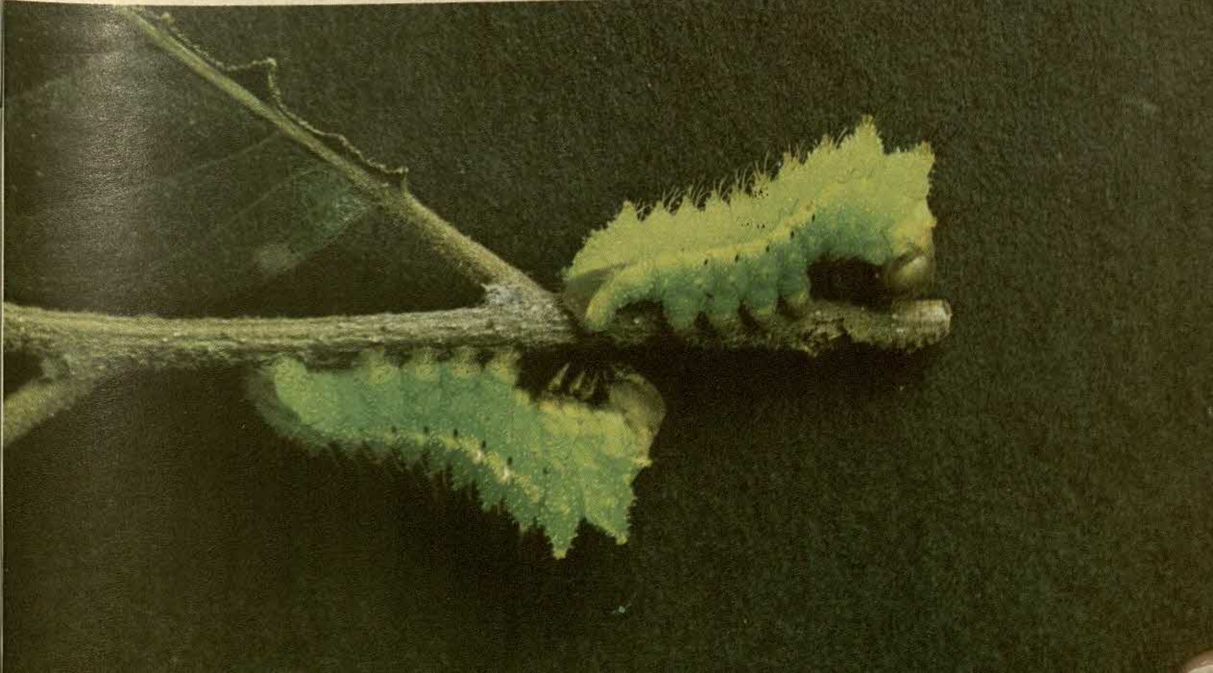


PLATE 14 (*below*). Japanese oak silkmoth larva, showing tufts of yellow hair characteristic of the fourth larval stage.



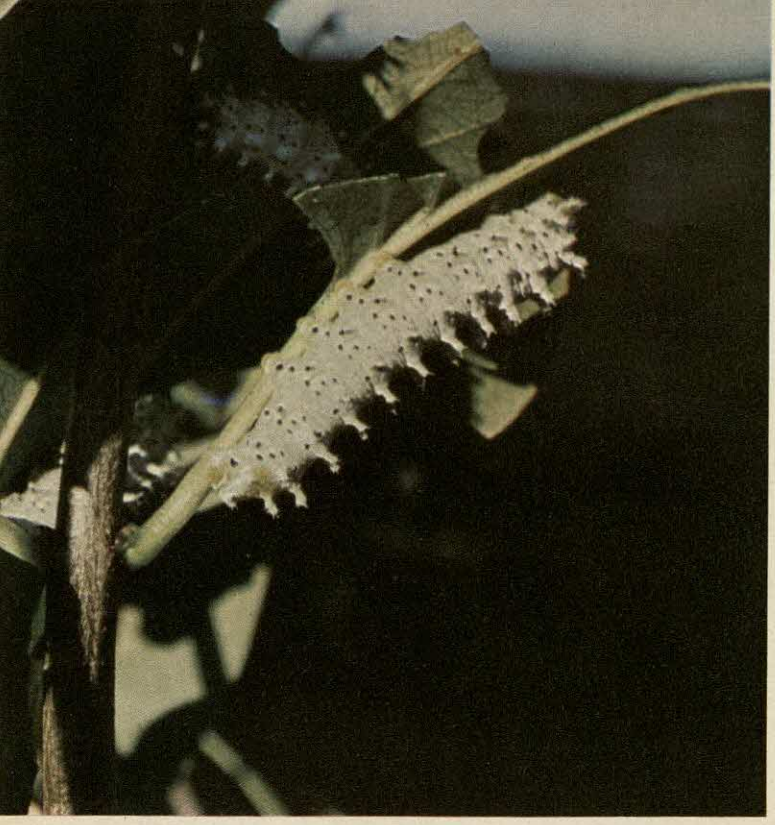
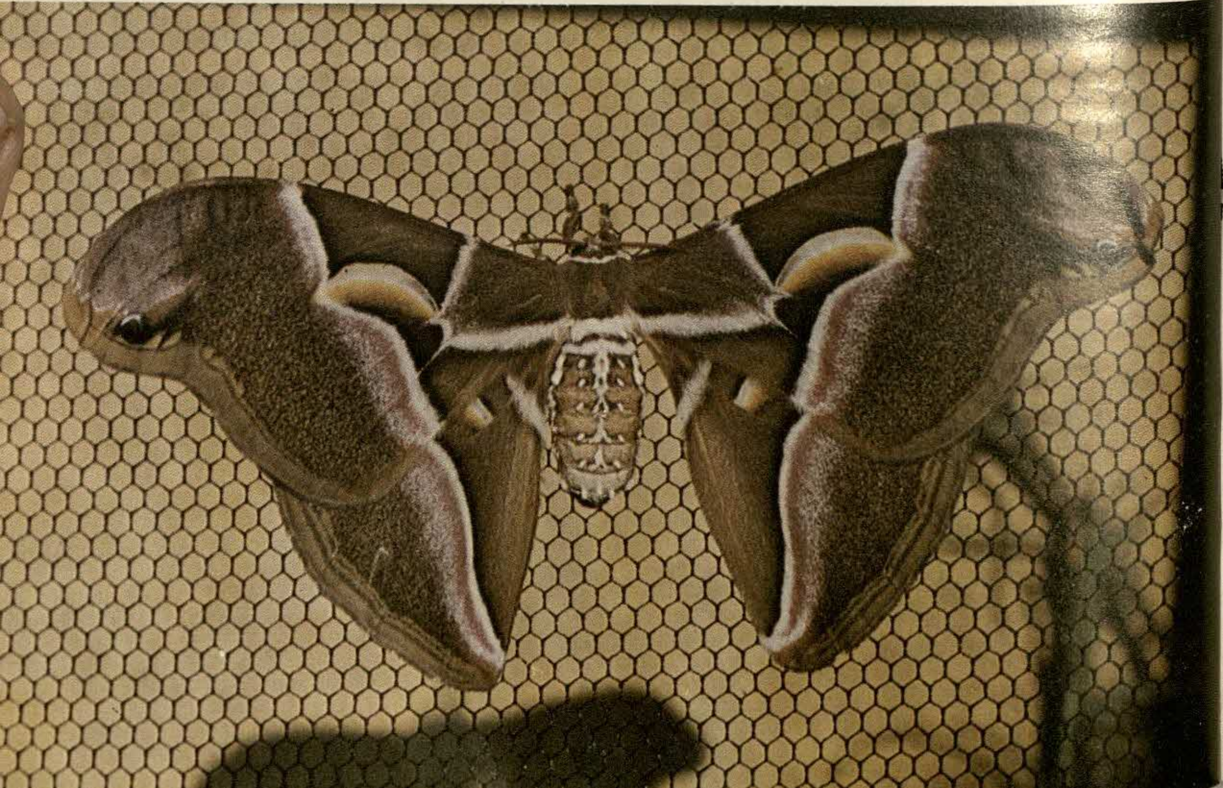


Plate 15 (*left*). Ailanthus moth larva in the fifth stage on privet.

Plate 16 (*below*). Adult female ailanthus moth clinging to nylon mesh.



Part Two: Plants

Chapter 6

Growing plants in the classroom, greenhouse, and school garden

Classroom conditions

LIMITING FACTORS

ROOMS DESIGNED to accommodate people, whether as dwellings or work places, are seldom satisfactory for the growth of plants. The most limiting factor is the poor light. Even in bright, modern classrooms the light intensity is far below that in the open air so that growth tends to be weak and spindly, except in plants adapted to poor light intensities. A layer of dust on window panes further reduces the amount of light penetrating into the classroom.

The warmth of a centrally heated building is a mixed blessing to the plant grower. This and bad light together tend to promote rapid stem growth coupled with poor leaf development. Those of us who have tried growing broad beans and peas indoors are well aware of the contrast between these 'drawn' plants and the sturdy, large-leaved specimens cultivated out of doors.

Many classrooms have a dry, dusty atmosphere. The lack of moisture in the air causes the leaves of plants to lose water rapidly, particularly in warm weather. No harm comes to the plant unless it runs short of water. Then the wilting and death of the leaves may follow quite quickly. Plants with relatively delicate leaves such as some ferns do not thrive in dry air. Dust also spoils the appearance of a plant and may clog the stomata (pores in the leaves) so much that the growth of the plant is slowed down.

CHOOSING PLANTS

There are two complementary lines of approach open to the person who wishes to grow plants indoors in these far from ideal conditions.

First, knowing the type of conditions in the room (a subject he may need to investigate), he should take particular care to select appropriate plants. Obviously one cannot be dogmatic about which these are since there are so many factors affecting the growth of plants, including the amount of care and attention they receive, but we give a list below in which we group some of the commoner plants grown indoors according to their requirements of light. Some of these plants have other features which might help them to survive and even thrive in the conditions of the classroom.

Growing plants indoors (*indicates a tolerant plant)	*Characteristics* *See key, p. 213*
1. Plants for sunny windows: (Some may need shading from very strong sun.)	
Campanula isophylla	C H F
Citrus sinensis (orange, lemon, grapefruit)	S H
**Cobaea scandens* (cup and saucer vine)	F S Cl B H
Eucalyptus globulus (blue gum)	S H B
Francoa appendiculata (bridal wreath)	H F
Jasminum primulinum (white jasmine)	F Cl H C B
Ricinus communis (castor oil plant)	S B
Pelargonium zonale (zonal pelargonium)	C F
Tropaeolum (nasturtium)	S Cl F
Succulents, e.g.	
Aeonium arboreum	C G D
Agave americana (century plant)	G D
Aloe variegata (partridge breasted aloe)	G D
Kalanchoe	
Cacti	
Kleinia articulata (candle plant)	G D

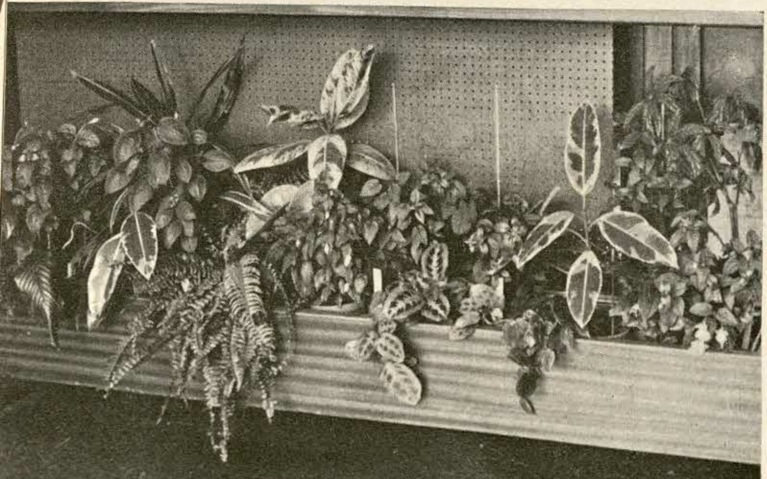


Fig. 51. An attractive group of house plants in one container, with the tall and long-leaved plants at the back.

2. Plants for semi-shade:

Asparagus sprengerii *Asparagus plumosus* (asparagus fern)	B H
Begonia semperflorens	C F
Cissus antarctica (kangaroo vine)	B C H
**Cobaea scandens* (cup and saucer vine)	S Cl B H
Coleus (painted leaf plant)	C
Cyperus diffusus (umbrella plant)	W
Fatshedera lizei	C B H
Ficus elastica (rubber plant)	B
Hedera (ivy): some varieties	C H
Helxine soleirolii (mind your own business)	M W
Impatiens balsamina (busy Lizzy)	C
Lonicera japonica aureo-reticulata (golden honeysuckle)	C H Cl
Mimosa pudica (sensitive plant)	S
Nepeta hederacea variegata (ground ivy)	H
Pilea cadierei (aluminium plant)	C
Primula obconica	S F
Saxifraga sarmentosa (strawberry geranium)	H
Sedum sieboldii (stonecrop)	H D G
Sparmannia africana (African hemp)	C B H
Streptocarpus (African primrose)	F L
Tolmiea menziesii (pick-a-back plant)	H L
Tradescantia: some varieties	C
Vinca major variegata (greater periwinkle)	C H

3. Plants for very shady places:

Chlorophytum comosum (spider plant)	G
Ferns, e.g.	
Asplenium bulbiferum (spleenwort)	L
Cyrtomium falcatum (holly fern)	H
Pteris cretica (brake fern)	
Hedera (ivy): many varieties	C
Maranta leuconeura (prayer plant)	
Peperomia: many varieties	L
Rhoicissus rhomboidea (grape ivy)	C

Key to plant characteristics:

B	Eventually requires a large pot, and grows into a big plant		
C	Grown from cuttings	H	Hardy—will stand cold
Cl	Climbing plant	L	Grown from leaves
F	Grown for its flowers	S	Grown from seed
G	Gas-tolerant	W	Requires a lot of water

Secondly, one can try to improve the conditions for plant growth in the part of the room where the plants are kept.

Plant troughs (as explained on page 215) can raise the humidity locally. Figure 52 illustrates one type, which is easy to make.

Materials

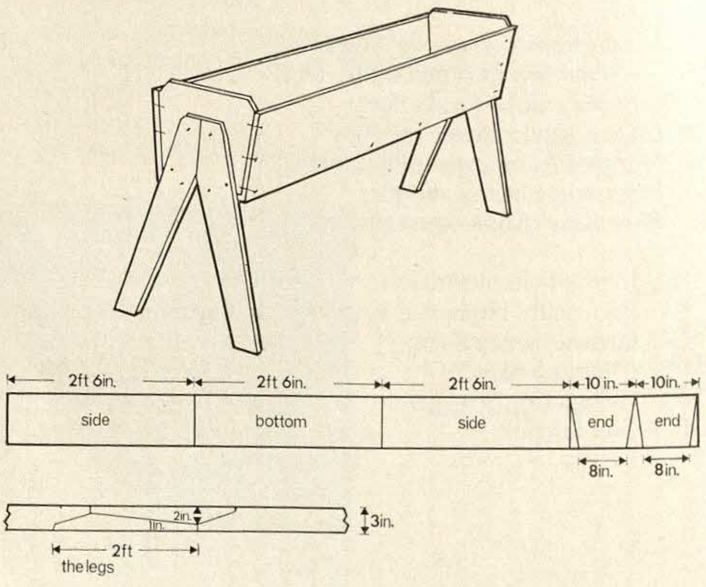
Deal or western red cedar	9 ft 6 in. x 8 in. x 1 in. or ¾ in.	for trough
Deal or western red cedar	5 ft x 3 in. x 1 in.	for legs
Brass screws 24	2 in. No. 8s	for trough
12	,, ,, ,,	for legs
Sheet Polythene for lining		

Also, the plants might be enclosed in some form of chamber where conditions can be more closely controlled. The following are some of the devices we have found most useful:

Indoor greenhouses

Where a dry atmosphere, dust, and draughts make it difficult to grow plants, or where better conditions are needed to enable a wider range of plants to be grown, or propagation carried out, some sort of 'indoor greenhouse' can be devised to give the plants a better environment. At its simplest this could be a sheet of Polythene pinned to a window frame to form a sort of tent to keep out dust

Fig. 52. A plant trough easily made from deal or western red cedar.



and to retain a little of the moisture evaporated from the plants and soil. 150 gauge is cheap and is available in several widths.

A better arrangement is for the plants under the canopy to stand in 2 or 3 in. of moist peat in a shallow tray. This is a positive way of maintaining a suitably moist atmosphere. You can buy galvanized trays, but it is quite easy to make one with a sheet of oil-tempered hardboard and four pieces of wood about 1 in. thick and 4 in. wide for the sides. Western red cedar is a suitable timber. These should be screwed together and to the base, preferably with brass screws. Though this is not essential, the box can be sealed with a lining of Polythene or thin roofing felt. The size of the trough will of course depend on the space available, but it should not be too deep from front to back or the children will have difficulty in reaching plants at the back. Twenty inches is satisfactory, and if it could be 4 ft long, it will hold a most useful collection of plants.

If this trough can be heated to 18°C or 21°C it will enable the class to grow a considerable variety of plants and, more important, to try a wide range of propagation methods. The simplest form of heating would be to fix the tray over a radiator but this would have a limited value because the radiator would be off in the summer term when the greatest variety of material for propagation would be available and again during the Christmas holidays when the plants' need for warmth would be greatest.

The ideal solution, if money is available, is to fit the greenhouse with a thermostatically controlled soil warming cable. A 75 W *screened* cable costs £3. It is 20 ft long and so it can only be fitted in a fair-sized structure at least 2 x 3 ft. The cable is laid zigzag on the bottom of the tray on between 1 and 2 in. of sand and covered with another layer of sand. Peat may then be put on top of this. Peat should not be put directly round a soil cable because if it dries out it is an excellent heat insulator and the cable may overheat and be ruined. Soil thermostats cost about five pounds but an aquarium thermostat costing 15s, mounted vertically, is quite satisfactory.

All electrical fittings must be wired by a competent person. Even so, it is as well to insist that children switch off apparatus such as this when they are working with it and to devise some system to help them to remember to switch it on again afterwards.

Cheaper, unscreened, soil warming cables are available at about £1 10s, but besides having no safeguard in case the insulation should be damaged, they are more difficult to lay.

Where the arrangement suggested for supporting the Polythene is not satisfactory a simple framework of wood or wire can be made but in such a case it might be more convenient to use one of the wire-reinforced transparent plastics such as Claritex. This is self-supporting and need only be bent into an arch and secured to the tray in some way. Cover the ends with Polythene curtains, to allow access to anyone taking care of the plants. 18 in. is a suitable height.

Propagating frames

The requirements for a propagating frame are similar to those for an indoor greenhouse—it must maintain a moist atmosphere, allow light to reach the plants, and provide suitable warmth. In a warm room, the simple expedient of a 5 in. flower pot, filled with a suitable rooting medium (see page 245) and covered with a plastic bag gives satisfactory results with many plants. The bag should be fixed tightly to the pot with a rubber band, to keep moisture in. Condensation occurs on the plastic and this often causes leaves to rot if they are in contact with it. Two or three small sticks can be stuck in the soil to keep the bag away from the plants and prevent this damage. Taking this idea still further, one can dispense with the pot, and root cuttings in a Polythene bag containing a couple of handfuls of compost and with the top folded over and sealed with paper clips. In this way every child can have his own propagating case, for to save space the bags may be suspended from a piece of string hung across the windows. Sweet jars and transparent plastic sandwich boxes are other alternatives.

The better types of propagator have the heat source underneath the plants—so-called 'bottom heat'. This encourages root growth without undue heating of the leaves which might cause wilting.

A small propagating frame can be made out of two halves of biscuit tins, one half-size and one full-size. Grow the plants in the larger tin, filling it with 4 in. Vermiculite (see page 22) containing a thermometer, and putting a glass sheet in place of the lid. Put a bulb of 15 W, or other wattage to give a temperature of 21°C to 27°C, inside the smaller tin, screwed into one side, invert this tin, and put the larger one on top. If the temperature in the upper tin rises above 27°C, ventilate the lower one by propping up the lid on two pieces of wood.

Larger propagating frames on the same principle can be made out of two drawers from an old chest. The base of the upper one should be replaced by a sheet of metal so that heat is quickly transferred to the rooting medium.

The upper box should fit snugly on the lower. The lower should have two lamps in one of the longer sides, to give the required temperature of 21°C to 27°C; and the lower should have a gap cut in the side opposite this. Some simple arrangement can be made to open and close this gap to control temperature.

Soil warming cables can be used for large propagating frames, but the installation should be checked by an electrician.

Bottle gardens

A bottle is the simplest sort of greenhouse. Gardens in carboys or other large bottles always create interest if they are well arranged. Once they are established they can be left for long periods with no attention at all. Even with the lid fixed on tightly the plants will thrive if they were initially healthy and if the situation is not cold. The soil must, of course, be moist to begin with. Moisture is evaporated from the soil and from the leaves of the plants, and it condenses on the sides of the bottle and runs back to the soil so that there is a continuous cycle—the hydrological cycle in miniature. The plants produce all the oxygen they need and the limited amount of carbon dioxide in the air, supplemented slowly by that produced by soil micro-organisms, is sufficient for the limited growth that is required. In practice, with narrow-necked containers, it seems to make little difference whether the stopper is in or not.

Carboys are expensive and very bulky, so something much less pretentious is best for the classroom. One gallon jars are a suitable size though much smaller containers may be used if the smallest plants are chosen. Sweet jars are ideal in school, because the wide necks make it possible for children to manipulate plants easily and to clean out the jars and replant, or change the compost to enable experiments to be carried out. Flat-sided jars are best as they will rest firmly on their sides, which not only give a large surface for planting but make access easier. They are available in various sizes from the scientific equipment dealers. 7 lb is a good size.

John Innes Potting Compost or a sand and peat mixture is satisfactory. Ordinary soil may give unsatisfactory results because it will probably contain weed seed and, more damaging, moss spores, which may germinate to form a thick green mat over the soil. If several similar containers are available several different media can be tried. Sand, peat, ordinary soil, Vermiculite, sand and peat mixtures, and John Innes Compost would be worth comparing. Comparisons of soils and the effects of fertilizers are notoriously difficult to carry out and evaluate, but here, in these small, controlled environments, there is the possibility of clear results.

Before starting to set up one of these gardens, wash out and the wire-reinforced transparent plastics such as Claritex. This is self-supporting and need only be bent into an arch and secured to the tray in some way. Cover the ends with Polythene curtains, to allow access to anyone taking care of the plants. 18 in. is a suitable height.

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Before starting to set up one of these gardens, wash out and thoroughly dry the container. If the inside of the glass is wet during the filling process, soil may stick to the sides of the bottle and be difficult to remove. Two or three inches of compost are needed in the bottom of the bottle, according to its size. This can be poured in with the help of an improvised paper funnel. The plants can then be dropped in through the neck of the bottle and pushed into position with a stick. All that is needed in the way of planting is to scrape a shallow depression with the stick, push the plant roots into it, and scratch a little soil over them. It does not matter if they are not properly covered, for in the very moist atmosphere they will not dry out, and new roots will soon form and penetrate the soil. When you are not able to obtain plants small enough to pass through the neck of the bottle, you may use cuttings instead. Conditions will be ideal for rooting, especially if the bottle is kept in a warm place.

If the compost is moist to begin with, there is no need to water immediately. In any case, this is only occasionally necessary, and it must be done with caution; if the soil is flooded nothing can be done to remedy matters. These gardens are complete little biological systems in miniature and should stimulate many questions worth following up, and give many opportunities for experiment.

Of the plants listed as house plants (pages 253-9) the following are suitable for bottle gardens:

Asplenium
Chlorophytum
Cyperus
Hedera helix
Peperomia
Pilea
Plectranthus
Pteris
Tradescantia
Zebrina

Taller plants like *Cyperus* obviously cannot be used in the smaller containers.

Other plants worth trying are:

Begonia bowerii BEGONIACEAE Mexico
A charming little prostrate species with small bright green leaves marked with deep purple at the edges. Delicate little white flowers.

Begonia rex BEGONIACEAE Assam
This is the species with huge attractively marked leaves in a wide range of colours and patterns. Apart from its appearance it is worth growing because it can be grown from small pieces of leaves. Most varieties are difficult to grow under room conditions but small plants do well in bottles.

Begonia masoniana (Iron Cross) BEGONIACEAE New Guinea
A striking plant, rather like *Begonia rex*, found quite recently in New Guinea. Mid green puckered leaves with a deep purple mark like an irregular cross.

Cryptanthus BROMELIACEAE Tropical America
Flat rosettes of stiff pointed leaves. They grow on trees.

Ficus pumila MORACEAE Japan
A creeping plant with small heart-shaped leaves.

Helxine soleirolii URTICACEAE Corsica
Spreading plant with tiny leaves. Very useful so long as it can be kept under control. The pale yellow form is even more attractive and is not likely to spread too much.

Peperomia caperata PIPERACEAE Brazil
Small heavily puckered and folded lustrous deep green leaves.

Peperomia scandens variegata PIPERACEAE
Trailing plant with pale green and cream foliage.

Sink gardens

Old sinks have several uses and are always worth scrounging. Sink gardens might be considered by those who have no soil out of doors. If the sink is stood on a stout board fitted with castors it will be fairly easy to move about. Shallow sinks, as we have considered in Chapter 3, might also be used as pools in outdoor vivaria for amphibia and reptiles. (See page 116.)

Old dustbin lids, inverted and supported on a square wood frame, are very suitable for moss gardens, etc.

Wood boxes can make effective 'sink gardens', but the wood eventually rots unless it is treated. Western red cedar is one type of wood that is very resistant to fungal attack and therefore rots very slowly.

In the school greenhouse

DESIGN

More and more authorities are providing schools (including primary schools) with greenhouses or plant porches or at least some sort of bay window extension to the classroom in which plants can be grown. In some schools the greenhouse is built against the outer wall of a main corridor, with a large window in the wall so that all the children are able to share in the enjoyment of the plants and the greenhouse does not become an isolated unit, used by the chosen few in the 'top class'. It ought to be heated. An unheated house is largely a waste of money, contributing little to the range of plants the school can grow in other ways and failing to provide interesting material in the winter when it is most needed.

The house must have enough ventilation and a moist atmosphere. All too often, small houses are little better than solar ovens in hot weather, with high temperatures and dry atmospheres. In these conditions few plants can thrive. The floor should not be concreted all over, but slab paths should be laid where needed, leaving bare soil below benches. This will not only provide a site for shade-loving plants to grow in but will contribute to the moisture in the air. Benches should not be slatted but solid, with a 3 in. rim round the edge or gravel trays placed on them so that they will hold a 2 in. layer of gravel. If this is kept wet it will keep the air round the plants moist. Some sort of shading will be necessary in the summer to prevent temperatures from rising too high and the plants being scorched. This is usually achieved by spraying the outside with a shading compound. Inexpensive split cane roller blinds are available for shading.

SOME POSSIBILITIES

A small greenhouse will make it possible to grow a much bigger range of plants for study. Far more house plants can be tackled, since the more difficult ones can be put in the greenhouse to recuperate after a spell in the classroom. Amongst these are interesting epiphytes such as the elkshorn fern, *Platycerium*, with fronds remarkably like the horns that give it its name and others adapted to collect debris round the roots so that the plant makes its own 'pot' of 'soil'. Pineapple relatives such as *Aechmea* also grow on trees, and the centre of the rosette in these plants forms a vase which fills with water and supplies the plant even though the roots may be dry. Seeds such as grape, melon, and peanut may be sown, not just for the young plants but in the hope of seeing mature fruit produced. Pomegranate will produce its attractive flowers. *Mimosa pudica* (the sensitive plant) can be raised from seed, and the way it immediately folds its leaves when touched makes it a favourite. Passion flower, so called because its parts have been associated with the Crucifixion, is also grown from seed.

The greenhouse will also enormously increase the range of plants that can be grown in the open garden, for all sorts of half hardy plants can be propagated for planting outside in the summer.

In the school garden

DESIGN

School surrounds are usually grass or tarmac, and though these may offer certain opportunities for study their very uniformity restricts their use. The main purpose in creating a garden in a setting is, by introducing something that completely contrasts with it and growing as many different plants as possible, to give children numerous chances to explore, experiment, observe, and discover. It should be planned and used, not as a place where gardening techniques are to be learnt, though the children will no doubt master useful techniques in the course of their work here, but as a place where explorations are stimulated and carried to fruition. Its aim will not be to produce good crops or beautify the school. The study of birds, insects, weather, and soil will be every bit as important as the study of the plants which are being cultivated. So an unhealthy plant, with caterpillars or aphids on it, will sometimes be equal in interest and educational value to a perfect specimen.

A space will have to be left where the younger children can plant their seeds—and perhaps dig them up again a couple of days later to see if they have grown—and carry on their other 'finding out' activities. This need not be large but it must be easily accessible, and preferably surrounded by a good hard-surfaced path.

WILD GARDENS

One of the most useful parts of a primary school garden could be the wild garden, an area allowed to run wild so that grasses and weeds will take over. These and the birds, mammals, insects, and other creatures that make their homes amongst them can be studied.

This might well develop out of the forestry plot. A small area will have to be kept clean for the raising of seedlings and growing on of young plants, but older trees planted a couple of yards apart and growing more strongly could well form the backbone of this wild part.

LAWNS

If space allows there should be a lawn, possibly the central feature of the garden, which can be a meeting place and around which the other features are arranged and activities carried out. This would give the open space necessary for the school's weather station, and here also one or two pets might be kept—a rabbit in a Morant hutch, for example. It would, itself, be a fairly complex plant community and a good place to start quantitative studies of plant communities: a lawn has the simplicity of a single layer of plants, which is rare in natural vegetation.

A GARDEN POOL

No feature interests the children more than this. Apart from the interest of the water itself there is the fascination of all the creatures that make their homes in it. If a microscope is available the children will see that there is no discernible limit to the variety of such life and will explore it with immense excitement. Quite young children can share in the joy of discovery through the microscope.

Now that 500 gauge Polythene sheet is available in lengths of 12 and 24 ft, 12 ft wide, any school with a little garden space can enjoy a pool with scarcely more effort needed than that required to dig a hole of the required size. Thus, a school can dispense with the professional labour and skill needed to make a concrete pool—and most of the cost. The sheeting is about 7s per yard so that, allowing for a double thickness, a pond of about 8 x 6 ft could be built at a cost of £2 2s for the plastic. Other more durable materials such as butyl rubber are also now available. They are more expensive than Polythene.

Polythene tends to perish after a couple of years or so, though black sheeting seems somewhat more resistant than the normal transparent kind, but, even so, the cost will be no greater over a period than that of a concrete pool.

A foot or fifteen inches is a satisfactory depth of water though if fish are kept it is advisable to make the middle rather deeper. If the soil is reasonably firm it may be possible to shape the hole so as to provide ledges at the corners or sides where the water will only be 2 or 3 in. deep and where marginal plants can be grown, but if this is not possible these can be planted in pots or boxes propped up to the necessary height on bricks.

Once the hole is dug to the required shape, remove all sharp stones and other objects which might penetrate the plastic. Couch grass shoots are in this category. As a further precaution, it is a good idea to spread peat, soft sand, or newspaper over the area to a depth of about 1 in. Lay the first thickness of Polythene on this, and if possible, separate this from the second thickness with another similar layer of sand or peat. Children should not be allowed to jump into the hole, as they love to do, once the plastic is in place. Once the water is run in, the sheeting will be forced to take up the shape of the pool, and the weight of the water will hold it in place.

There are no harmful chemicals to deal with as in a concrete pool, and planting can take place straight away.

The area immediately round the pool will receive a lot of wear and if it is unpaved it will become slippery in wet weather and could cause children to fall in. The sides could also cave in. To avoid these dangers, give the observers a firm, dry foothold in all weathers, and also to secure and hide the edge of the plastic, it is best to surround the pool with an edging of paving slabs. 2 x 2 ft slabs, 1½ in. thick, are ideal. They are quite expensive, about 5s each, but they make an enormous improvement, not only to the utility, but also to the appearance of the pool.

PLANTING

Floating, floating leaved, submerged, and marginal plants should all be included if possible. No doubt the children will demand a water lily. These are expensive, and if you have to buy one make sure its size is suited to the depth of water in the pond. With a water lily, you will have one of the bottom-rooted plants with floating leaves. *Aponogeton distachyus* (water hawthorn) and *Villarsia* (water poppy) are two others. Frogbit is a good floating plant. Duckweed is almost certain to become a nuisance and should be kept out of the pond.

Elodea (Canadian pondweed), *Fontinalis* (water moss), *Potamogeton*, and *Myriophyllum* (water milfoil) are good submerged oxygenators.

Alisma (great water plantain), *Sagittaria sagittifolia* (arrow head), and *Pontederia* (pickerel weed) can all be planted in up to a foot of water and their flowers and leaves will project well above the surface.

Finally, there is a wide range of plants that will grow in an inch or two of water or in wet mud at the margins of the pond. Interesting ones include:

Acorus (sweet flag) and its variegated variety
Butomus (flowering rush)
Calla palustris (bog arum)
Caltha palustris (marsh marigold) and its double form *plena*
Glyceria spectabilis variegata—a variegated grass
Iris pseudacorus (yellow flag iris)
Juncus spiralis (corkscrew rush)
Lythrum (purple loosestrife)
Mentha aquatica (water mint)
Menyanthes (bog bean)
Mimulus luteus (monkey flower)

Myosotis palustris (water forget-me-not)
Scirpus zebrinus (zebra rush)
Typha minima—a diminutive bulrush

Several of the plants listed are natives of Britain and it would do no harm to collect small portions from the wild where they are growing abundantly. If the class does this, however, the teacher should leave the children in no doubt about the need for great care in removing wild plants.

POSSIBILITIES FOR STUDY WITH FOOD PLANTS

In our efforts to get away from the old ways, when school gardens were little better than allotments and the emphasis was on acquiring the manual skills needed for producing crops successfully, we have gone rather too far. We are apt to undervalue the interest children show in growing food plants and the benefit they can derive from it. Yet food plants are those with which children are usually most familiar, perhaps not as living, growing things, but on the table or in the greengrocer's shop, and very often these are the plants they choose to grow when the choice is theirs. Since they are particularly suited to measurement and experiment there is every reason for including them in the school garden.

Why do we thin the seedlings? What happens if we do not carry out this operation? What effect does thinning have on total yield and on size of individual plants?

Two or more varieties of, say, potatoes may be compared for yield. What precaution must we take to see that our results are valid? This might lead the class to compare early and late varieties and to discuss why early varieties are worth growing in spite of their lower yields, why it is important to maintain supplies of food throughout the year, problems of storage, and the much more difficult problem of assessing quality.

Why do we sow different seeds at different depths? What happens if we sow a particular seed nearer the surface or more deeply?

What is the effect of not weeding? How do the weeds affect the crop? Throughout the work in the vegetable garden there is endless opportunity to measure length and area, weights of crops and fertilizer, averages, costs of seeds, and value of yield.

The plots may be quite narrow, for as much may be learnt from ten cabbages as a thousand, and the routine work must be kept to a minimum so that the garden does not become a liability.

There is plenty of opportunity for comparing plants and classifying them in various ways. For example, the crops might be grouped into plots under the labels, 'Roots we eat', 'Leaves we eat', and so on. Some are annuals, some biennials (what happens if we leave a parsnip or leek in the ground for a second year?), and some perennial. Some are hardy and will stand all weathers, and others can be sown after the risk of frost damage is past and are killed when autumn frosts come. Where do these plants come from?

Some need to be pollinated before they can yield a crop. How is this brought about? Here there is an opportunity to consider pollination by wind, taking, say, maize, as an example, or by insects, as in broad beans. Some plants, such as peas, are self-pollinated and others, such as marrow, may have separate male and female flowers and may be hand pollinated.

All sorts of vegetative characters are there to be observed—twining stems in runner beans—do they always twist the same way? Which way? How does this compare with other twiners? Tendril climbers in peas and marrows, for example. Which plants have root nodules? What are they? Can we find the wild ancestors of, say, carrots, parsnips, and cabbages? Can we find wild relatives of other plants? (It is not always safe to assume that a wild flower is the ancestor of a garden relative. For example, garden roses are not descended from the wild rose but are complex hybrids from a number of species from as far away as China.) Why do we earth up potatoes, leeks, and celery? What happens if we don't? What are the effects of lack of light on plants?

Fertilizer experiments are notoriously difficult, even for skilled scientists, for there are so many variables of soil and climate to affect the results, and a reasonably fertile soil may well contain enough nutrients to mask the effect of added fertilizer. This, added to the time taken for the crop to mature, makes nutritional experiments less useful than many other activities in the school garden.

Cereals and other farm crops could be included in part of the garden. Some of the commoner forage plants might appear, including some of the more important grasses.

Here, too, a few fruit bushes could be grown—currants, gooseberries, blackberries, raspberries, and strawberries are all easy to propagate and grow and will provide material for propagation and study.

If there is room for an apple tree, and funds will allow, it would be fun to get a family tree, in which three or four varieties are grafted onto one tree. This will bring home very effectively to the children the way in which grafting can be used to grow one plant on the roots of another. The commercial grower has to follow the development of his trees through the season very carefully, noticing the various stages of growth so that various pest and disease control measures can be applied at the right time. 'Dormant bud', 'bud burst', and 'green cluster' when the leaves are just opening, 'pink bud', open flower, petal fall, fruitlet June drop, and fruit ripening are all stages that need to be noted. Their names give clues to the particular development taking place, and children could be encouraged to time them and to find out what work the grower has to do at each stage and why. They can compare trees of different varieties and different kinds of fruit in the district. They can also notice the effect of weather conditions, not only on the trees but on the numbers and kinds of insects visiting them. Frost effects are particularly important. The number of flowers on a twig, a branch, or a tree can be estimated and the number of mature fruits compared with this. What is the effect of fruit thinning? How many fruits fall at the June drop? What is the yield of a tree? What weight would there be if every flower developed a mature fruit? Could the branches stand this weight? What weight will a twig bear? What weight will twigs of other trees bear?

POSSIBILITIES FOR STUDY WITH WEEDS

Weeds are a nuisance, but if they are nothing more than this in the school garden then an educational opportunity is being missed. How did they get there? Which were carried by the wind? Which by birds? In what other ways might they have arrived? Were there seeds already in the soil? How many in a given sample of soil? How long can they survive in the soil?

How do they spread other than by seeds? Can we trace the 'roots' of couch grass or other organs which cause it to spread? How many young plants will a creeping buttercup produce in a given time? What area can it colonize in a season?

How many seeds can a given weed produce? One group of children found the charlock plants in their school garden produced over eight thousand seeds each! How long does it take a given weed to grow to flowering size? For how many months can plants such as groundsel be found in flower? Do they produce more than one generation in a year? Are all the plants of a species about the same or do they differ widely in these characteristics?

Apart from the characteristics mentioned above, how are weeds adapted to withstand our efforts to get rid of them? How deep can we trace underground stems and roots? Which of them can sprout again, like docks when we cut the tops off? How many can root again, like cuttings, when we have hoed them off? In what form do they survive the winter?

POSSIBILITIES FOR STUDY WITH PESTS

From the educational point of view, pests, as well as weeds, may be welcome since they provide many opportunities for investigation.

Which part of the plant do different pests attack? Leaves, as caterpillars do? Roots, as with wireworm? Seeds, as with the maggots of the pea moth in pea pods? Which pests attack one type of plant only, and which attack several? Which are like slugs and attack many different parts of a plant?

How do they attack? By sucking the sap as greenfly do? By biting the leaves, like caterpillars? By tunnelling in the leaves like leaf miners? By forming galls and living in them like cabbage root fly? By living in the soil and attacking the roots as leather-jackets?

What protective adaptations have they? Camouflage as the caterpillar of the small white butterfly has? Warning coloration like the cinnabar caterpillar? Nocturnal habits like slugs? Living in the soil as wireworms do? Jumping, like the flea beetle? A waterproof covering, like woolly aphis and cabbage aphis? Waxy roof, such as scale insects?

What sorts of creatures attack our plants? They are not all insects; there are slugs and snails, millipedes, woodlice, mites, etc. What harm is done by mammals? By birds? Blackbirds eat our strawberries. Are they pests or do they make up for this? What else can we observe them eating? Which birds do harm? Which help us by eating pests? Which are both harmful and helpful?

When are worms helpful? Where are they a nuisance?

Which insects help us by eating other insects? Can we find young ladybirds or the young of hoverflies? Can we find the cocoons of the parasite which destroys large white caterpillars?

Bees, of course, help us by pollinating flowers. They can be watched in action. What kinds of flower do they visit? Do they seem to have any colour preferences? How many kinds of bumble bees can we find? Which are their favourite flowers? Watch them at work on broad beans or bergamot and see if they 'cheat' by biting through the floral tube. What other kinds of insect visit flowers? What preferences have they? (Bumble bees and some flies are better than hive bees at pollinating early fruit blossom, as they work in lower temperatures.)

What ways do we use for destroying garden enemies? (Some methods of trapping pests are interesting, e g. grease-banding for female winter moths. How does this work?) What methods are used for trapping earwigs? Slugs? Wireworms?

A cabbage or Brussels sprout plant may be a veritable zoo of pests and their predators and parasites. Small white caterpillars may be there, well camouflaged in green and lying perfectly still alongside a vein at the base of the leaf. In contrast the caterpillars of the large white butterfly are a conspicuous yellow with darker markings and are to be found eating together in groups. Sometimes a dead caterpillar will be found surrounded by the little yellow cocoons of the parasitic ichneumon fly, *Apanteles*. We have considered some of these points in Chapter 5, page 164. Birds and diseases also reduce the numbers of large white caterpillars, and it has been estimated that of every ten thousand eggs laid, only about thirty-six reach maturity. Cabbage aphids, protected by their waxy coats, may be present and some of them may have been parasitized by a minute chalcid wasp. If so, their skins will have turned to a straw colour and may show the tiny exit holes where the parasite has escaped.

Other enemies of the aphids will probably be present. Most easily recognized are young ladybirds. Hoverfly larvae are also common. Both are very different from the adults, as we saw in Chapter 5 (page 162). The changes of form undergone by insects during their development are as remarkable as they are commonplace. The large white butterfly is a good subject to study in this context, for the female butterflies are often seen settling on cabbages to lay their eggs, and the groups of these are easy to find on the undersides of the leaves. The young caterpillars stay in a group to feed and are also easily found, and they become more conspicuous as they grow. A few nearly mature specimens can be collected and allowed to pupate in the classroom and should produce either the butterflies or, equally interesting, some of their parasites.

The brown caterpillars of the cabbage moth may also be present, and the roots often contain large swellings, which, when opened, reveal the white grubs of the cabbage root fly. It is by no means uncommon to find most of these insects on a single plant!

Of course one can have too much of a good thing, and it will be necessary to check pests from time to time. There are several good insecticides on the market which are non-poisonous to mammals and birds, and these will deal with the general run of pests. Cheap hand sprayers are useful. Soil pests such as slugs and wireworms can be dealt with by baiting.*

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* Bibliography and other particulars for reference for all the chapters on plants will be found at the end of chapter 9, page 286.

Chapter 7

Plant cultivation indoors

Basic principles

SOIL AND COMPOST

SOIL IS A very variable commodity. Part of it is mineral matter consisting chiefly of particles of sand, clay, silt, calcium carbonate, and calcium phosphate, and part organic matter, this being the decayed and decaying remains of animals and plants, known as humus. Air and water must also be reckoned as part of the soil since they occupy spaces between the solid particles. Dissolved in the water are small but significant amounts of chemicals, chiefly salts such as calcium bicarbonate and calcium nitrate, with even smaller amounts of others containing the elements hydrogen, sodium, potassium, iron, and aluminium in the form of carbonates, bicarbonates, nitrates, sulphates, etc. In addition the soil teems with living organisms such as bacteria, fungi, protozoa, worms, moles, and, of course, plants.

Because all these components, living and non-living, organic and inorganic, are an integral part of soil, it is not surprising to learn that it is difficult to make an artificial soil. We can take so much for granted when growing plants out of doors, but as soon as we try to grow plants in pots or boxes we have to face the fact that small quantities of soil undergo quite rapid changes, which are usually so much the worse for the plants under cultivation. Soil taken from the ground and placed in a plant pot loses some of its characteristics during the transfer, for the packing of the soil particles is always altered, and this affects drainage and air content.

To be satisfactory, a soil or soil substitute must provide anchorage, water, and nutrients for the plant. Its texture must be such that it allows easy root penetration, good drainage, reasonable water retention, and good aeration. It must be free from toxic substances and harmful organisms, and it should be neutral or slightly acid. Scientists at the John Innes Institute have developed a medium with these properties which can be used for most plants grown in pots or boxes. It is called the John Innes Potting Compost. It consists of:

7 parts by volume loam
3 parts by volume peat
2 parts by volume coarse sand
To each bushel (four two-gallon buckets),
  $\frac{3}{4}$ oz ground chalk
  $\frac{1}{4}$ lb John Innes base fertilizer, consisting of 2 parts by weight hoof and horn meal; 2 parts by weight superphosphate; 1 part by weight sulphate of potash

All the ingredients must be thoroughly mixed. The loam should be sterilized by heating to 82·2°C for 10 minutes to kill weed seeds, harmful insects, and disease producing organisms. This may be done by heating the loam in a piece of sacking over a bucket of boiling water, but this is hardly a job for the classroom, and for general purposes, a reasonable imitation of John Innes compost may be made with unsterilized soil.

All this may seem a lot of bother, when the ready-made compost can be bought at a horticultural shop. However, mixing it at school may raise a number of questions worth following up, such as:

Why add sand? Why add peat? Which of the ingredients allows water to drain through most quickly? Which retains most water? Do we need to sterilize the loam? Are there any insects in it? Any weed seeds? Why add the different fertilizers? Why add ground chalk? Do plants grow as well if we omit this or that ingredient? In addition, there is the opportunity to measure by weight and by volume (why by volume?) and to work with proportions.

Because of the difficulty of getting good loam a number of soil-less composts have been devised. Most of these are mixtures of peat and sand in various proportions, with added fertilizer. A simple recipe suitable for schools is to mix three parts of peat with one of sand and provide nutrients by feeding the plants with a proprietary liquid fertilizer.

Healthy plants may be grown in Vermiculite (see page 216) provided they are regularly watered with a liquid fertilizer.

Variations on the John Innes potting compost are available, such as John Innes seed compost, but the potting compost is quite adequate for most seeds.

POTTING AND REPOTTING

With modern potting composts it is usually not necessary to put drainage crocks in the bottom of the pot although, of course, this depends on the size of the drainage hole in relation to that of the particles of compost. To pot up a plant, put a little potting compost in the bottom of the pot, and hold the plant in position with one hand while putting more compost around it with the other. Press the compost down gently with the finger-tips, making sure that the plant is central in the pot, so that it is at the same depth in the soil as previously, and that a gap of half to one inch, according to the size of the pot, has been left for watering.

If an indoor plant, particularly a slow-growing one, is put in a pot which is far too big for it, there are not enough roots to absorb the soil moisture, and therefore the soil lies wet and may rot the roots. Most types of indoor plant only need repotting when they are really pot-bound, that is, when the pot appears to contain an almost solid mass of roots with hardly any soil visible when the plant is knocked out of the pot. To knock out a plant from its pot to examine the roots, put one hand over the top of the pot with two fingers on either side of the plant. Turn the plant upside down and tap the rim of the pot sharply on the edge of the table. The whole 'soil ball' should come cleanly out of the pot with no disturbance to the roots. Unless the roots completely fill the pot, the plant is best left alone. Where repotting is necessary it should be left to the spring or summer when the roots are growing most vigorously, and the next largest size of pot should be used.

On the other hand, plants which grow very rapidly, such as tomatoes, thrive in large pots with plenty of compost for the roots to exploit. Tomato seedlings can be transplanted direct from the seed pan into 5 in. pots and later moved to 10 or 12 in. pots.

FEEDING

When a plant has occupied the same pot for a year or so the soil may become exhausted, and feeding with a liquid fertilizer, strictly according to the maker's instructions, will be advantageous. Too strong a dose will possibly kill a plant. Little and often is the best rule and feeding is not needed at all in the winter months when little or no growth is taking place. Regular feeding is essential when plants are grown in Vermiculite or unfertilized sand and peat mixtures.

WATER AND HUMIDITY

Watering is one of the most skilful operations required of the pot plant grower, whether amateur or professional, and more plants are ruined by faulty watering than any other factor. It is impossible to give straightforward rules for watering, since the need for water depends on the kind of plant and a variety of environmental factors.

Generally, the amount of water needed by a plant varies with temperature and light intensity. In bright, warm weather in late spring and summer, most plants need plenty of water and the soil should be kept permanently moist. In dull, cool weather they need little watering—just enough to stop them from wilting. In late autumn and winter, in particular, water must be given most carefully, and it is wise not to keep the soil 'nice and moist'. It is far safer to allow it to become almost dry before watering.

Most plants recover remarkably quickly when watered if they have wilted through the soil being too dry, provided that they have not been in this state too long and the tissues have not become too desiccated. If a plant wilts when the soil is wet, then it has probably been overwatered, with consequent rotting of the roots. This is much more serious. Further watering will make the damage worse, and the best thing to do is to keep the plant in a warm place with the soil almost dry, in the hope that it will form new roots.

A plant may be suffering from drought when the soil is apparently wet, for the surface soil may be wet while the soil lower in the pot may be quite dry. When this condition is suspected the pot should be stood in water up to the rim so that the soil becomes thoroughly moistened, for once soil is very dry it is surprisingly difficult to wet it by watering from above. With a little practice it is possible to tell whether a pot plant needs watering, by lifting it to judge its weight. Obviously it will weigh considerably more when the soil is wet, and conversely it will seem light when the soil is dry, even if this is concealed by a wet surface. Children sometimes water plants superficially and it is a useful exercise for them to apply this test.

Some experts advise using tepid water in cold weather to avoid chilling the roots, and while this can do no harm, there seems to be little evidence to justify it. Scientists at the John Innes Institute found that it made very little difference whether seedlings (of six species, including tomato and *Primula malacoïdes*) were watered with cold or warm water (Lawrence 1948).

Soft water should be used if available in areas where the water contains much lime, for this may make the soil too alkaline for some plants.

During the winter, plants can usually be left for several days with no danger of drying out, especially if the room is cool. In summer, a hot weekend may prove dangerous to them, and they are not likely to be able to survive a half-term holiday unattended, unless some precautions are taken. The plants should be stood on the floor in a shady place and the entire plant and pot enveloped in a Polythene bag. This can be secured to the pot with a rubber band. Water, evaporated from the plant and soil, condenses on the bag and trickles back into the soil. This device also increases the atmospheric humidity. Some plants can be protected against drought for considerable periods by this method. Others are less accommodating and practical experience is the only safe guide.

Some house plants with leathery leaves, such as *Philodendron*, *Monstera*, and *Ficus*, do not wilt easily but begin to turn yellow if the plant is too dry. The same thing happens, however, if the plant is too wet, too cold, or suffering from the effects of fumes, so this symptom should be investigated with caution.

Plants which are able to tolerate poor light usually have their natural habitats in forests or other shady places where the atmosphere is humid. Ferns and some house plants fall into this category and the dry atmosphere of the classroom can be a serious handicap to their growth. A daily sponging or spraying of the foliage with tepid water helps to keep them healthy, but is too time-consuming for most of us. The solution must lie in keeping the atmosphere immediately round the foliage as moist as possible. The pots may be stood on plastic or metal trays containing wet pebbles, the water level being maintained just below the surface of the layer of pebbles. Evaporation from the trays keeps the atmosphere above them more humid than the rest of the room. Here are two ways of maintaining a constant water level in the trays, using sand in them:

1. Stick a glass or plastic inspection tube into the sand, and pour water into this until it is $\frac{1}{2}$ in. below the surface. Do not put crocks in the bottom of the plant pots.
2. Cut a hole in a plastic bottle $\frac{1}{2}$ in. below height of sand surface, stand the bottle in a tin with a perforated base, fill the bottle with water (keeping thumb over the hole) and screw on the top, and put the tin with the bottle into the sand.

It is also possible to make a plant self-watering in the following way. Put a wick through the pot so that it protrudes at top and bottom. Rest the pot on another shallow, upturned pot standing in water in a container, so that the wick end is in the water. Pebbles may be used instead of the upturned pot. Glass wool makes a good wick.

Another solution is to group the plants in troughs or other containers with the pots plunged to their rims in moist peat. The moisture given off by the leaves of a plant in the group benefits its neighbours, while evaporation from the peat contributes more moisture to the atmosphere. With this system, it is generally possible to water less often, especially where clay pots are used, for less evaporation will take place through the sides of the pots. There is less likelihood of plants drying up completely if watering is overlooked and, conversely, it is possible to withhold water longer from plants which might suffer from overwatering. The more vigorous plants often root through the bottoms of the pots into the peat and grow more strongly in consequence. See Chapter 6, page 214, for the construction of plant troughs.

On the smallest scale, little groupings of plants may be made, even in a 5 in. pot. It is surprising how a group of three or four different kinds of plant, grouped together, will cover up one another's deficiencies so that several individually poor plants may be brought together to form a pleasant and effective group.

LIGHT

All plants which contain the green pigment, chlorophyll, need light for healthy growth. Diffused daylight is essentially the same kind of light as sunlight but of lower intensity. Generally speaking, this 'natural' light is the best kind for plant growth. Artificial light from tungsten filament lamps is a moderately satisfactory light source for plants, fluorescent light is rather better, and that from mercury vapour lamps better still. Some tomato growers use mercury vapour lamps in their glasshouses during the winter months to secure very early crops.

Out of doors, plants may be found thriving in various conditions of light intensity, ranging from continuous exposure to full sunlight or daylight to total shade. Those plants with the greatest need for light can be grown successfully indoors only if special precautions are taken. The light intensity indoors is always rather less than that outside, because of shading and loss of light by reflection as it passes through glass. When choosing plants to grow indoors, it is important to bear in mind the kind and quality of light available. Most kinds of cacti do best in sunny windows, whereas many of the commoner house plants thrive in semi-shade. Indeed, these shade-tolerant plants should not be put on a south facing window sill in summer where intense sunlight may damage or kill them. It is advisable, however, to move these plants nearer to the light source during the months October to April, because the intensity of light is so much less during the winter.

When plants of the same kind are grown in different parts of a room the differences are sometimes striking and more often than not, are caused by differences in light intensity. For the same reason, the summer growth of a plant can be quite different from the winter growth. Variegated ivy (*Hedera canariensis*) tends to produce larger leaves in summer, whereas the lengths of stem between successive leaves are smaller than those produced during the winter months. The proportion of green to yellow in the leaves is affected by the amount of light, seemingly while the young leaf is growing most rapidly. The leaves of a few variegated kinds, such as the ivy *Hedera helix* Chicago *variegata*, may lose much of their attractive patterning in poor light and turn almost uniform green. They should, of course, be given the lightest positions. (This loss of variegation should not be confused with 'reversion' to plain green which occurs in some shoots of variegated plants such as *Tradescantia*. This is a permanent change and as such shoots tend to be more vigorous than the desired type they may overgrow the rest of the plant unless removed.)

AIR AND FUMES

Plants need both oxygen and carbon dioxide, the former for respiration and the latter for photosynthesis. It is highly unlikely that either gas will be in such short supply as to affect the growth of plants kept indoors. When plants are kept in a closed container of small volume such as a bottle garden, there is a possibility of a carbon dioxide shortage, but even here it is a remote possibility rather than something to be guarded against.

Fumes can have disastrous effects on plants grown indoors. Gas, paraffin fumes, and those from coke fires are harmful to many plants and may cause leaves to turn yellow or fall off. If the fumes are unavoidable it is wise to choose those kinds of plant known to be resistant to their effects.

TEMPERATURE

The hardier indoor plants will stand relatively low temperatures—down to 7°C in many cases—and a few such as some ivies and *Tolmiea* will actually tolerate frost. The higher the minimum temperature that can be maintained the greater the range of plants that can be grown. The worst danger periods for classroom plants are winter weekends and the Christmas holidays. When heating is not maintained during these periods children may be prepared to take plants home. For emergencies of, say, four or five days, plants and pots could be rolled in several layers of newspaper or stood in a deep box and covered and surrounded by newspaper and straw. Plants should be kept as dry as possible at such times, for they are more susceptible to damage when the soil is wet.

Even in a warm room, cold air may flow down the glass of the window on a frosty day, while leaves touching the glass may be severely damaged. Where there are curtains which, when drawn, would isolate the plants from the warmth of the room, the situation is even worse. Tender plants are much better away from window sills in cold weather.

Draughts are as harmful to plants as they are to humans. A plant in the draught of a door or ill-fitting window in an otherwise warm room may suffer severely.

Conditions may be too hot as well as too cold. Few plants could survive immediately above a radiator or a fireplace. Shrivelling leaf tips and edges are a sign of conditions that are too hot and dry. Sometimes the cooler conditions of corridors—provided that they are not draughty—will be more suitable than those of the classrooms.

Useful equipment

Rather than provide a comprehensive inventory of tools and materials used in plant cultivation, we mention those items we have found particularly useful in schools.

TOOLS

Trowel—At least one blunt nosed trowel is needed, preferably more, since this is the most useful tool for handling small quantities of soil.

Spoons—These are better than trowels for dealing with very small amounts of soil.

Dibble—This is useful for making small holes when pricking out seedlings, but a pencil will do (see page 241).

Spade, garden fork, rake, hoe, etc.—Only necessary for outdoor gardening. Strongly made small garden tools suitable for children are manufactured by Edward Elwell Ltd.

Watering can—The Haws pattern, 1 gallon size, is nicely balanced and the rose slides on to the spout. Smaller plastic watering cans are handy for indoor use with small numbers of plants.

Secateurs—Are much better than scissors for cutting twigs, etc.

Sprayer—One such as the double action type made by Solo Sprayers Ltd is very useful in a greenhouse to humidify the atmosphere or spray liquid insecticide and fungicide. A small pressure sprayer is handy for indoor use in small plant houses and propagating frames.

Seedboxes—Greengrocers can sometimes supply grape and tomato boxes cheaply. These are rather deeper than the standard seed box and therefore more suited for pricking out seedlings (see page 241). Fish boxes are usually well made but it is a little difficult to remove the smell.

Plastic plant pot troughs—These vary in strength. The thicker grades are suitable to hold moist gravel or Vermiculite on which several pots are stood. (See pages 215 and 233.)

Roofing felt—Can be easily formed into box-type containers for growing plants. (See also page 219 for particulars of sink gardens of various types.)

Claritex is a clear plastic sheet reinforced by 1 in. or 2 in. wire mesh. The 2 ft width costs about 3s per ft, but 25 ft rolls are relatively cheaper. It is useful for making cloches and propagating frames, discussed on page 216.

PLANT POTS

For school use, terracotta coloured plastic pots are much more satisfactory than the old clay pots. They are easy to clean, whereas clay pots easily become discoloured and are then very difficult to clean. A clay pot dropped to the floor will be smashed but plastic pots usually withstand this sort of treatment. They are very light and easy to carry by comparison with clay pots, and they also take up less storage space.

Plastic pots cost about the same as clay pots, although prices vary. The brightly coloured types tend to be very expensive and have little to recommend them.

For most classroom puposes 3½ in. pots are suitable. They will do perfectly for small plants, either grown from seed or cuttings. Large plants need 5 in. pots. Where space is limited, for example in a classroom propagating frame, 3 in. pots could well replace the 3½ in. size. They occupy surprisingly less space and use correspondingly less compost. Of course, with a smaller pot, there is a greater likelihood of the compost drying out, but this is not a great problem inside a propagating frame where conditions should be humid.

For bulbs, 6 in. and 8 in. clay pans are ideal. They have pleasing proportions, similar to those of a bulb bowl, and are, in fact, wide, shallow flower pots. These are not yet available in plastic, though plastic half-pots are satisfactory for bulbs. These are shallow flower pots; 6 in. in diameter is the largest size available at present.

If new clay pots are used they should be soaked in water for a few days before use to remove any harmful chemicals that may have been formed during the firing.

Many different kinds of foodstuffs (cream and yoghourt for example) are now packed in plastic containers and many of them make excellent flower pots if a drainage hole is made at the bottom.

Plastic plant pot saucers are useful for their prescribed purpose, but also make handy shallow containers to hold water, paint, etc. They can be used as base and lid of insect cages, as we have discussed in Chapter 5, page 171.

A comparison of plant growth in plastic and clay pots can be illuminating. The walls of the plastic pot are waterproof and 'gas-proof'. What effect does this have on plant growth?

Chapter 8

Plant propagation

Seed

OUR CIVILIZATION could hardly continue without the crops we produce by the annual sowing of seed. Moreover, even where crops come from perennial, vegetatively propagated plants such as fruit trees, we must use seeds to develop new varieties. Only sexual reproduction, or cross-pollination between different varieties can combine the desirable characters of each variety to produce even better ones.

Seeds are ideal for study in the classroom, for it is easy to obtain a wide variety, they take up little space, and results are quick.

SOWING SEEDS INDOORS

Seeds may be sown in pots, pans, or boxes, according to the quantity of plants to be raised and their vigour. Where, as will often be the case in the classroom, only a few plants of a particular kind are needed, a 3½ in. pot will usually be satisfactory. If large seeds such as beans or acorns are being sown, only one should be put in each pot. Small pots not only take up little space but they also save compost.

John Innes Seed Compost is specially formulated for seed sowing and is therefore ideal, but John Innes Potting Compost is also perfectly satisfactory for most seeds and if it is already in there is no need to buy and store a second kind. Sand and peat mixtures are quite satisfactory, provided that, if they contain no added fertilizer, the seedlings are pricked out as soon as they are large enough. This is even more important where Vermiculite is used, for though seeds germinate very well in it, it contains no nutriment at all. Some of the pre-sown seed packs on the market have the seeds sown in Vermiculite and sometimes include a packet of nutrients.

Potting composts of the John Innes type have a fairly coarse texture so there is often no need to have crocks in the base of a pot, either to improve drainage or stop particles of compost falling through. Pots for seed sowing should be filled with compost which should be carefully pressed firm with the tips of the fingers. The final smoothing and pressing can be done with the bottom of another pot or jam jar. The finished surface should be about ¾ in. from the rim of the pot. Stones and lumps must be removed. Fine seed should be scattered carefully on this surface; larger seed may be spaced individually ½ in. or more apart. A gardener's rule of thumb is that seed should be covered to twice its own depth. The finest seeds should have no soil cover at all, average flower seeds will need about ⅛ in. of fine soil sifted or sprinkled on them, while the largest can be about ½ in. deep. In the last case the covering should be gently made firm so that the finished soil level is about ¾ in. below the top of the pot.

Figure 53 illustrates the sowing of seed.

The seeds must be watered very carefully or they will be washed out of the soil. The safest method is to stand the pots in water to about 1½ in. from the top and allow the water to rise up to the soil surface. They should then be stood in a warm place and covered with a piece of glass to prevent drying of the soil. A Polythene bag will do. It is usually recommended that the glass be covered with a sheet of brown paper, but this is not necessary. Most seeds do not need to be kept in the dark to germinate satisfactorily. A few kinds do need darkness, but equally some need light. The danger with covering with paper is that if the seeds germinate and are not noticed the seedlings may become drawn and weak. As soon as the seedlings are seen the pots should be stood in a light place, but not in direct sunlight, which may cause the soil to dry out rapidly. At no stage must the seed or seedlings dry out. With many kinds of seedlings the pot may be completely enclosed in a Polythene bag and will need no watering for weeks, but others may 'damp off' under such conditions and a certain amount of trial is needed.

Damping-off is a fungal disease which causes seedlings to collapse. It is encouraged by overcrowding and still, humid air. Nothing can be done about plants which are already infected but the spread of the disease is checked by watering with Cheshunt Compound, which is available from sellers of horticultural sundries.

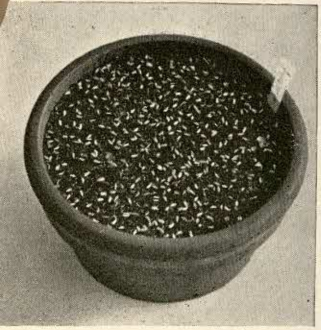

Fig. 53. Sowing seed.

All pots should be carefully labelled with the plant name and the date. The sower's name can be put on the other side of the label. Only pencil should be used—ink runs and ballpoint ink fades.

A common mistake is to sow seeds of tender plants too early. The light and perhaps also the warmth available are insufficient for healthy growth, and the shoots grow poorly. Moreover, those that the grower intends to plant in the open eventually may be ready long before conditions outside are suitable.

Where seeds are sown in boxes the filling of these needs a little more care. Fill them loosely until the soil is level with the top. Then make the soil firm with the finger tips, starting with the corners and continuing with the edges. Then level out the soil, using a flat piece of wood to give an even surface.

PRICKING OUT

The seedlings should be given more space as soon as they are large enough to handle. This is when the cotyledons are fully developed and the first pair of normal leaves are developing between them. If they are allowed to get bigger a lot of root damage may occur when they are moved.

For pricking out (see figure 54), the grower needs to fill a pot or seed box with potting compost and level this as for seed sowing. The seedlings should be planted about $1\frac{1}{2}$-2 in. apart. Alternatively, where there are only a few, they may be pricked out into 5 in. or larger pots or pans, or, if they are quick-growing kinds, put straight into 3 in. pots. Where boxes are used it is advisable to mark the rows on the soil surface to ensure even spacing. Five rows of seven plants in a standard seed box is a good spacing for school purposes, though commercial growers may put many more plants than this in a box. The numbers will depend on the species.

The grower should lift the seedlings carefully, digging well under them with a wooden label or old knife so that the roots are not damaged. He should then separate them, holding the leaves to avoid damage to the stem. Now he should make holes in the new soil with a pencil and lower the roots in carefully, making sure that they hang straight down and are not folded back. The soil should be pressed round them down to the roots, but the stem must not be squeezed. They may be watered, using a can with a fine rose if one is available or, in the case of pots, soaked in the same way as seeds. They should be kept out of the sun for a few days.

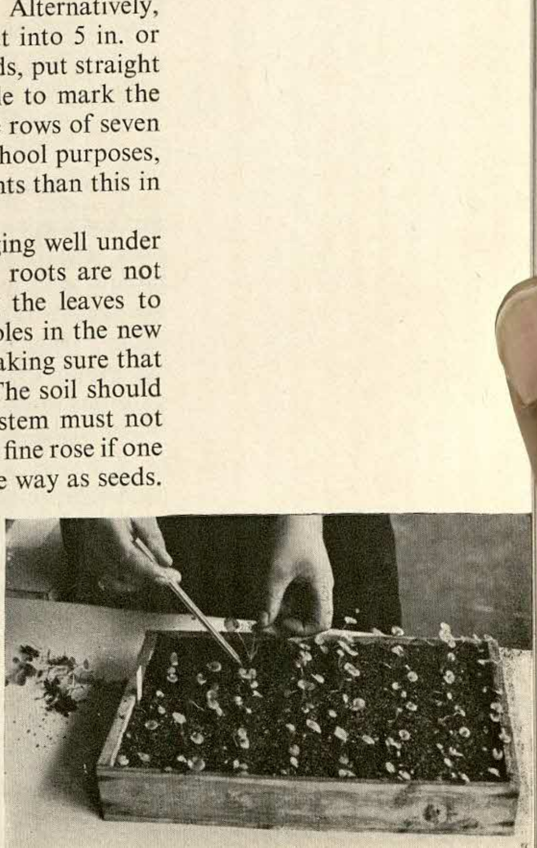

Fig. 54. Pricking out seedlings.

SOME POSSIBILITIES FOR STUDY WITH SEEDS

Seed variation

Children may become interested in the characteristics of the seeds themselves and wish to make a museum to show something of the variations:

Size—This ranges from the dust-like seeds of orchids and begonias to the coconut.

Shape—Varying from the nearly spherical form of a pea to the extreme elongation of the grain of some grasses, the flattened disc of parsnip, and the winged and plumed extensions which aid wind dispersal in other plants. (Technically grass and cereal grains and the 'seeds' of the daisy family are fruits, while 'seeds' such as those of the parsnip and sycamore, where the fruit often splits in two, are half-fruits, but need we be pedantic about this at this stage?) How effective are these extensions? How much farther does a winged sycamore seed or a plumed dandelion seed travel than those from which these extensions have been removed? How far can we trace ash or sycamore seedlings from an isolated tree? How far do elder, hawthorn, holly, or seedlings from other fleshy fruits appear from the parent bushes? Can we find seeds in bird droppings?

Colour—Plenty of variety here, too. How many different kinds of dwarf and runner bean seeds can you find?

Texture—Hard, smooth, papery, hairy, woolly, wrinkled, spiny, etc. A magnifying glass will reveal many beautiful structural markings as well as colour patterns on seeds.

Uses—Food, drink, spices, oils, animal food, children's games, etc.

Seed structure

Soaked seeds of peas or beans are best for observing the tough seed coat, the food-storing cotyledons and, wonderful discovery, the complete little plant inside. But what happened when we soaked the seeds? They grew in size. Do they weigh more? How much more? Which seeds swell most? Which swell most quickly? Can we graph the increase in weight over several hours? What precautions must we take in doing this? Does the temperature of the water make any difference?

Germination

Will our seeds germinate more quickly if we soak them first? How long do they take to germinate? Do all seeds of one kind come up together or is the germination period spread out? A great deal of interesting graph work may come out from enquiries such as these. The question of whether to record the number of seeds germinating each day or the cumulative total will have to be decided, and the decision may bring about discussion of the appropriate sort of graphs to use in each case.

Do all our seeds come up? If not, what percentage germinates? Does this vary with different kinds? Different ages? How do varying conditions affect results? Depth of sowing? Temperature? Light?

For germination tests a hundred seeds are usually used, but smaller quantities may be satisfactory in the classroom. Discussion about the need for satisfactory sample sizes may arise here. Obviously one seed would not do. The required number of seeds can be counted out on to moist blotting paper or, better still, damp cotton wool, in a saucer or tin lid. They must not be allowed to dry out and this can be avoided by putting the experiment in a Polythene bag. The sprouted seeds are removed, counted, and recorded daily. As wide a variety of seeds as possible should be tested—vegetable and flower, farm and weed seeds. Vegetable seed packets usually bear some reference to the Seeds Acts and many catalogues list the required germination and purity percentages. This might lead to consideration of the ways in which the law protects consumers and the way in which scientists carry out tests to ensure that the law is obeyed.

If a variety of seeds is sown the seedlings can be observed and comparisons made. A large number will produce two seed leaves. A few, such as grasses, cereals, and onions, have one long narrow seed leaf. Here we have monocotyledons and dicotyledons, though we should not use these terms in class. It is important for the farmer and gardener to be able to distinguish crop and weed seedlings, and children can learn to do this. Plants with much lobed or divided leaves usually develop these characters gradually, the first leaves being simple in shape and each succeeding leaf developing greater complexity. This provides opportunity for observation and recording. What happens to the food store in the seed? In which plants does it remain below ground and in which is it raised above?

How do weed seeds get into the soil? How many are there? What kinds? How many seeds do various weeds produce? Do they fall near the parent, or are they scattered? How? How far?

Why don't seeds grow in the packet? Must they have soil to grow? If not, what do they need? Children will discover the need for water and warmth and, less easily, for air, but do we need the traditional three beakers? Seeds in dry soil may be compared with those in wet soil. Some pots can be put in a warm place and some in the cold. And a few seeds in a corked bottle of water will demonstrate the need for air without such an artifice as putting some in boiled water with olive oil on top.

Beans and peas grown on blotting paper in jam jars continue to fascinate successive generations of youngsters. Jam jars are not the easiest of containers to deal with, however; so much of the time is spent poking about with rulers to get the seeds into the right place or remove mouldy ones! Nor are beans and peas the only seeds worth studying.

A foam plastic sandwich allows the grower to use small as well as large seeds, and to display them more effectively and handle them more easily. Take a sheet of foam plastic about ½ in. thick or a wad of blotting paper or cotton wool of similar thickness, wet it, and arrange the seeds on it. Sandwich this between two sheets of glass (alternatively one can be of hardboard which will do for the backing sheet) and bind together with strong string or some sort of adhesive tape. The whole can then be hung up like a picture. Sharp edges and corners of glass can be rounded off with an oilstone for safety and to prevent them from cutting the string.

The sandwich should be vertical to prevent the roots from growing into the plastic and being hidden. What happens if we tilt it on to another side? Why? What difference does it make if we cover it up with black paper? If the plastic dries out too quickly the whole case can be wrapped in a sheet of Polythene or enclosed in a Polythene bag.

Growth

Children often have difficulty in measuring the growth of their seedlings because the amount of growth is so small. With a strong shoot—from a pea or bean, for example—a growth lever can help. This is a light lever made of, say, cardboard, and pivoted nearer to one end—say five-sixths of the way along. If the short arm is moved the other will travel five times as far. The end of the short arm should be directly above the tip of the plant and attached to it by a thread. A scale can be put behind the other end. The amount of growth can then be read off, remembering that the actual growth is the same fraction of the amount registered as the short arm is of the long arm; thus, in our example, growth is one-fifth of the reading. The weight of the lever should be adjusted so that the longer arm is slightly heavier—just enough to keep the thread taut. This can be done with Plasticine or by sticking drawing pins in. This could lead to an interest in levers and ratio.

Propagation by cuttings

NECESSARY CONDITIONS

Children get a great deal of satisfaction from rooting cuttings, and if the right material is chosen and reasonable conditions provided, quick results, which are so important in school, can be achieved. Indeed, this method of propagation gives quicker and more positive results than most others. Which is the best compost? Does it make any difference if we remove some or all of the leaves? Do rooting hormones help? What are the effects of varying conditions—light, heat, etc.? What is the best size of cutting? Does it matter where the stem is cut? *Fuchsia*, *Coleus*, *Plectranthus*, *Pilea*, *Begonia semperflorens*, and chrysanthemum are all good cuttings to use. *Tradescantia* and *Zebrina* root very easily—so much so that they are likely to root whatever the conditions and so mask differences in treatment.

For good rooting the following conditions are needed:

1. A suitable compost which retains moisture yet is porous and well aerated, because oxygen is needed for the growth of the callus tissue which seals over the cut stem. Half sand, half peat, is a good mixture, and so is Vermiculite which is sterile and very light so that it is possible to lift the cuttings from time to time, to watch developments, without harming the young roots. Pure sand, pure peat, water, and various soils and composts can be compared.
2. Warmth. These cuttings root best at temperatures between 15·5°C and 26·7°C. Results are usually best if the soil is warmer than the air. To obtain this 'bottom heat' we suggest using heating elements under the soil in the propagating case (see page 216).
3. A moist atmosphere. The leaves of the cuttings still give off water vapour, yet until roots are formed this cannot be replaced, so the cutting is in danger of drying out unless this water loss is reduced to a minimum. This will be achieved if the cuttings are surrounded in a glass or plastic cover.
4. Roots can only form when the necessary hormone reaches the cut end of the stem. This is produced in the leaves and travels down the stem, but artificial hormones are often used by professional growers to ensure speedy rooting. Seradix B, manufactured by May and Baker Ltd, is a well-tried preparation, available from most gardening shops. Three strengths of Seradix B are manufactured for treating soft, medium, or hardwood cuttings. Dip the base of the freshly trimmed cutting into the appropriate powder before planting.

SOFTWOOD CUTTINGS

These are made of soft young growth, usually 2-4 in. long and preferably without flowers or flower buds. The majority of plants are best able to form new roots from the region of the nodes—that is, where the leaf joins the stem—and so the cutting should be taken off cleanly just below the node. The lower leaves are removed, not only because they might be buried when the cutting is planted and so rot, but also to help to cut down transpiration and so keep water loss to a minimum. At least one developed leaf should remain, however, to produce the hormone that stimulates root development. When prepared, the cuttings are planted 1-1½ in. deep round the side of a pot, and the compost made firm round them. A 3½ in. pot should take half a dozen cuttings planted in this way.

LEAF BUD CUTTINGS

With some plants it is possible to reduce the size of the cutting to a single leaf with a piece of the stem attached. These are called leaf bud or mallet cuttings. The stem will root at the node and the bud in the axil of the leaf will grow out into a new shoot. These may be planted round the edge of a pot as for ordinary cuttings, making sure that the base of the leafstalk is firmly in the soil. *Cissus* and *Rhoicissus* may be propagated in this way, though results are rather slow. With ivy the cuttings are too small to go round the edge of the pot and these are planted with the stem horizontal and the leaf sticking above the soil, the stem being covered with about ½ in. of soil.

LEAF CUTTINGS

A few plants are able to produce new shoots as well as new roots from a cut surface and these can be propagated from a single leaf. The leaves are detached with the leafstalk and are planted like cuttings. The most important of these plants is *Saintpaulia ionantha* (African violet), but this is difficult to grow and in the classroom the best plants to use would be peperomias and some begonias such as *Begonia bowerii*. As shown on page 257, *Peperomia magnoliaefolia variegata* gives plain green plants when grown in this way, but the variety Green Gold gives normal variegated plants. It is often possible to detach the leaf from the young plant, when it has formed, and use it again to produce another plant.

Begonia rex can be propagated from only a small part of a leaf. The largest leaves are cut into squares or triangles with sides of about 1½ in., and these are either laid on the compost or put in it edgeways, with the thickest part of the vein down. Vermiculite gives the best results in school because there is less likelihood of rotting. Another way of propagating this plant is to lay the complete leaf on the compost and to cut through the largest veins in several places. New plants then appear at the cuts.

Both leaf cuttings and leaf bud cuttings require similar treatment to softwood cuttings and offer similar opportunities for experiment.

A number of succulents will produce young plants from single leaves if these are gently pulled off the parent plant and laid on moist sand. Some varieties of *Sedum*, *Echeveria*, and *Pachyphytum* are in this group.

HALF RIPE CUTTINGS (MEDIUM HARD CUTTINGS)

A large number of shrubs may be propagated by cuttings made from side shoots of semi-ripe wood removed during summer and planted in sandy soil in a cold frame (which in the school garden may simply be a box with a sheet of glass on it). The shoots used should be short growths—between four and six inches long. By June or July these are usually fairly tough and woody (and therefore distinct from softwood cuttings), though not completely ripe. They may be cut below a node as for softwood cuttings, or they may be pulled off the parent stem to leave a 'heel'—a sliver of the old wood. The lower leaves should be removed before planting.

Conifers such as cypress and juniper may be propagated in this way from shoots 3-4 in. long with a heel, planted in sandy soil.

HARDWOOD CUTTINGS

Twigs of willow standing in a jar of water often produce roots, and if planted out they will grow into bushes. These are hardwood cuttings. Many shrubs can be propagated in this way from mature twigs planted during the winter. The shoots should be of sound, strong wood, produced the previous summer, about 9-12 in. long. They should be cut below a node at the bottom (i.e. below a bud), and the tip of the shoot should be cut off above a bud if it is not fully mature. They can then be planted in a slit cut with a spade in the open soil, half to two-thirds of the shoot being buried. Coarse sand is sometimes put at the bottom of the slit to assist rooting. The bursting of the buds is not a sign that the cuttings have rooted—often this happens when no rooting has occurred and then after growing a few inches they dry up. If growth continues after a month or so, then they probably have rooted. Forsythia, flowering currant, privet, and black and red currant root easily. So do willow and poplar; in fact fencing posts made of fresh branches of these trees sometimes take root. Poplar cuttings will sometimes make five or six feet of growth a year.

ROOT CUTTINGS

We soon learn from experience that it is no use just chopping off the top of a dandelion or dock to get rid of it. The cut end soon grows new buds and shoots and the weed grows as strongly as ever. This points to a way of propagating some plants with fleshy roots such as *Anchusa*, *Verbascum*, and oriental poppy. Thick roots are cut up into pieces about 3 in. long and planted in sandy soil with the cut end just below the surface. It is essential to keep them the right way up, and to avoid mistakes gardeners usually cut the top end straight across and the lower end with a slant. Phlox is grown from root cuttings but as the roots are much thinner, they are laid flat and covered with about ½ in. of soil.

Other methods of propagation

DIVISION

Very many plants, particularly herbaceous perennials, send up a mass of shoots and grow in more or less dense clumps. To increase the plant these can be dug up and pulled apart to give a number of smaller clumps. With plants that grow rapidly, such as Michaelmas daisies, the old clumps may be divided into single-rooted shoots, and these will soon form sizeable new plants. If the growth is very tough it may be necessary to cut through it with a knife or spade. Large old clumps of herbaceous perennials can sometimes be split by thrusting two garden forks into the middle, back to back, and levering them apart.

A few house plants can be divided in this way—ferns for example. Sometimes it is possible to divide storage organs so that each part contains a bud and is capable of making a new plant. The most familiar instance is when potato tubers are cut into pieces, each piece containing an 'eye'. Each will produce a satisfactory plant. It is best to allow the eyes to sprout before cutting. Large begonia tubers and gladiolus corms can be divided similarly, though usually only into two pieces. Where cuts are made into fleshy tissues such as these, it is best to allow the cut surfaces to dry before planting, to reduce the risk of rotting. Clumps of dahlia tubers may be split up, but in this case the individual tubers are not cut but each division should have a whole tuber and a piece of the stem bearing a bud.

It is wise to allow the buds to begin to sprout before dividing so that they can be seen easily.

Plants with creeping underground stems (rhizomes) may be propagated by dividing the rhizome system. Make sure that each new plant has a piece of rhizome and a bud or shoot. Flag irises are propagated in this way and so is *Elettaria.* It is also used inadvertently when the 'roots' of weeds such as couch grass are cut up by digging or ploughing and left in the soil.

SUCKERS

Suckers are shoots which arise from the ground some distance away from the parent plant. The distance may be a few inches, as with roses, or many yards, as with the common elm. The shoots may be dug up with a portion of root to form new plants, as is done with raspberries. A word of warning is necessary here. Many ornamental trees and shrubs and most fruit trees are grafted onto root stocks which are inferior in fruit or flower, from the top of the plant. Some of these, for example, plums and lilac, sucker freely, but the suckers will reproduce the rootstock and not the desired variety. Thus, suckers from a double white lilac will often give the common single mauve kind.

Sucker-like shoots which arise close to the main plant are usually called offsets, but there is no clear line of demarcation. *Cryptanthus* is propagated by offsets, as are many other rosette plants such as houseleeks.

RUNNERS

When the young plants are borne some distance away from the parent plant on long over-ground stems they are known as runners or stolons. Strawberry runners are familiar examples, while those of the creeping buttercup are equally familiar, though less welcome to the gardener. *Saxifraga sarmentosa* and *Chlorophytum* are two plants suitable for the classroom which are propagated by this method. To propagate such plants in pots, press or peg the young plants into a new pot of soil and leave them attached to the parent till they have rooted. In the open they usually root all too freely.

LAYERING

In a way, this is intermediate between taking cuttings and using divisions, suckers, or offsets. It is used where cuttings do not root easily, and the idea is to cause roots to form while the shoots to be layered are still attached to the plant. The simplest method is mound layering. This is used for shrubs which send up a number of shoots from soil level. If soil is moulded up round the base of these they will usually form roots. Where this is not possible, a branch may be bent down to ground level and the end buried in the soil with six inches to a foot of the tip bent to a vertical position projecting from the soil. To hasten the rooting, the part of the stem to be buried should be slit lengthwise down the centre, with the incision made at a node, or a piece of bark should be cut away. If necessary, push a forked twig or anything else which will act as a peg into the ground over the layered shoot, to hold it down. With outdoor carnations the shoots are prepared by cutting through the stem about six inches from the tip and the soil is mounded round the prepared shoots.

House plants are usually easily propagated by cuttings or other methods, but where difficulty is experienced thin stems could be pegged down into pots of compost alongside the mother plant to provide layers.

AIR LAYERING

More useful in the classroom is the modern technique of air layering, which may be used for plants with tall stiff stems which cannot be bent down to soil level. The stem is cut halfway through at a node as for layering, and if it seems likely to close, held open with a tiny pebble. Then the rooting compost is brought up to the stem and secured round the cut by being enclosed in a strip of Polythene 4-6 in. wide, tied above and below the compost. The soil may be peat, a mixture of sand and peat, Vermiculite, or, preferably, sphagnum moss, which is ideal for rooting and easy to handle. The compost should be well moistened and the Polythene should be firmly tied to prevent moisture loss. After a few weeks, if the work is successful, roots will be seen through the plastic, and the rooted top of the plant can be cut off and potted up. The lower part will probably send out new shoots which can be used for more propagation. This method is useful to produce compact new plants from kinds such as *Fatshedera* and *Ficus* which have lost their lower leaves and become 'leggy'.

It is interesting to note that although this particular form of air layering is a very recent innovation, the Chinese used essentially the same method thousands of years ago, to propagate citrus and other trees. They bound the cut stems with sphagnum moss and covered the moss with rush mats. In the last century special flower pots were made for the purpose, in two halves which could be fitted together round the stem and filled with soil.

TIP LAYERS

Blackberries and loganberries root and produce new plants when the tips of the shoots are pressed to the ground. To make sure of good contact put the tip into a slit in the soil and press the soil to hold it securely.

VIVIPARY

An interesting group of plants are those in which young plants are borne on the leaves or in place of the flowers. *Kalanchoe verticillata* and *Kalanchoe daigremontiana* produces cores of little plants on the leaves and these fall off and root in the soil below. *Tolmiea menziesii* and *Asplenium bulbiferum* produce much larger plantlets on the leaves, and these may be pressed flat against the soil to allow the young plants to root. The plantlets of *Asplenium* may be removed and potted separately but should be allowed to grow till the diameters of the rosettes are at least 2 in. across before this is done. Some members of the onion family bear clusters of bulblets on long stalks instead of flowers. The Welsh onion of gardens and the wild crow garlic are two of these.

BUDDING AND GRAFTING

Although budding and grafting are not likely to be carried out in many primary schools, children may wish to know something about the composite nature of many of our important garden plants such as roses and tree fruits. In these the head of the plant is made up of the desired variety while the roots are of some other variety which, while inferior in flower or fruit, provides a satisfactory root system and is easily propagated. Most roses, for example, are budded on dog rose stocks, which accounts for the occasional appearance of sucker shoots of different type from the rest of the bush. These must be removed, because they will only give dog rose flowers. In principle, this way of producing plants involves removing the top of the plant which is to provide the roots—the rootstock—and replacing it by a bud or small piece of stem of the desired variety—the scion. With suitably skilful 'carpentry' the two parts unite to form one composite plant. Usually the join is near ground level, but with ornamental trees it is often at the top of the main stem. It is often possible to point out the swelling and irregularity in the stem of a young tree which marks the graft union.

Chapter 9

Notes on selected groups of plants

Plants grown mainly indoors

HOUSE PLANTS

NOW THAT INDOOR gardening is becoming a very popular hobby, the range of available house plants is increasing. These are plants which remain attractive indoors for several months or even years. Nearly all house plants are grown for the beauty and interest of their foliage. Unfortunately, a good many tender and difficult varieties are on offer which are not likely to survive long in the average room. These are usually the more colourful and attractive kinds. Flowering pot plants such as cyclamen and azalea, which are difficult to keep and have a very limited period of attractiveness, obviously do not fall within this group, popular as they are in the home. Indeed, few that do come within the group can be persuaded to flower satisfactorily indoors. It is best to avoid any but the toughest until some experience has been gained in gardening under classroom conditions. One of the leading growers of house plants invariably sends them out with a colour-coded label: 'pink', 'blue', or 'yellow'. Those with a yellow label are particularly difficult, those with a blue label are moderately so, while those with a pink label are the easiest and most reliable. It is worth while writing to this firm, Thomas Rochford & Sons Ltd., 264 Flower Market, London WC2, for their very informative illustrated leaflets and wallcharts on house plants.

In compiling a list of house plants we have selected varieties which grow under the rather difficult conditions of the classroom, though some are easier than others. The list is arranged in alphabetical order of Latin names, with a common name as appropriate.

Admittedly, even the commoner varieties such as these are not cheap in terms of a primary school allowance, but more and more are appearing in the shops and prices are much more reasonable. Since they are fairly common, there is a good chance of obtaining spare plants or at least cuttings. Many secondary modern schools have collections of them, and the propagation carried out by gardening classes sometimes leads to an embarrassingly large number of young plants. The teachers of rural studies in these schools are often only too keen to help neighbouring primary schools.

Even the few plants listed here show what diverse regions of the world have contributed to our stocks of cultivated plants, and help to bring a little real-life geography into the classroom.

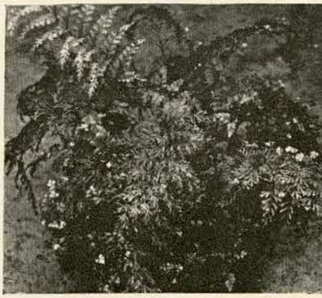
Fig. 55. *Asplenium bulbiferum* (spleenwort).

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Some reliable house plants

Asplenium bulbiferum (See 'Ferns', page 213 and figure 55.)

Begonia haageana (*scharffii*) BEGONIACEAE Brazil
Of the begonias grown for their foliage this is one of the easiest to manage. It has the characteristic lop-sided foliage of its family and this is brownish green and hairy and a good deal more attractive than such a description suggests. The pale pink flowers are not very showy but there are some on the plant at most times of the year. In any case, flowers are a bonus amongst foliage plants. Propagate it by softwood cuttings. *Begonia metallica* is equally easy to grow.

Billbergia nutans BROMELIACEAE Brazil
Most members of the pineapple family grow on trees in tropical America, but this one, like the pineapple itself, is terrestrial. It has clusters of long, green, spiny-eyed leaves like a miniature pineapple plant. The flowers are unusual in colour, being dark blue and green with protruding yellow anthers, and are enclosed in bright pink bracts. Propagate this by removing offsets.

Chlorophytum comosum variegatum (Spider plant) LILIACEAE South Africa
An easily grown plant which is valuable for its bright foliage. This is pale green with longitudinal bands of cream. The very tips of the leaves nearly always shrivel in the dry atmosphere of a room, but this does not detract seriously from the appearance of the plant. It is interesting because it bears young plants on the ends of grace-

fully arching stems. These may be pegged into pots to form new plants or they may be removed and potted up separately when they are big enough. It is best to wait until the tips of the new roots appear at the base of the young plant before doing this. *Chlorophytum* may also be propagated by division, which must be done carefully as the roots are fleshy and tender.

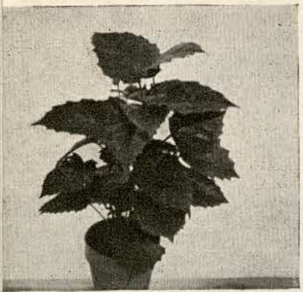


Fig. 56. *Cissus antarctica* (kangaroo vine).

Cissus antarctica (Kangaroo vine) VITACEAE Australia

A member of the vine family and vine-like in its appearance. It has dark green shiny-toothed leaves and is a tough and tolerant plant. Though it normally climbs by means of tendrils, it needs only a stake to keep it in order. Propagate it by cuttings or leaf-bud cuttings. It is rather slow in rooting. (See figure 56.)

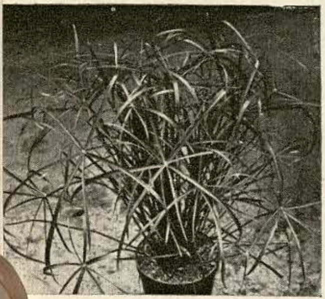


Fig. 57. *Cyperus diffusus* (umbrella plant).

Cyperus diffusus (Umbrella plant) CYPERACEAE Africa

A grassy plant (see figure 57) belonging to the sedge family which looks like a model palm tree, with its clusters of leaves radiating from the tops of the slender stems like the ribs of an umbrella. It is interesting in being related to *Cyperus papyrus*, which provided the writing paper of Ancient Egypt. *Cyperus papyrus* is somewhat similar in growth, though very much taller. It was probably *Cyperus diffusus* (and in any case not the bulrush) which gave shelter to the infant Moses. As it is a waterside plant it should be kept very moist at all times. It is exceptional amongst house plants in that it is easily raised from seed. One packet alone will give an inconveniently large number of young plants. Another means of propagation is by removing a tuft of leaves with an inch or so of stem and pressing this into the compost in a propagating frame so that the base of the cluster is firmly against the soil. A number of small plants will arise from the centre of the cluster if conditions are right.

Ecballium elaterium (Squirting cucumber) CUCURBITACEAE Mediterranean areas of Europe and Asia

Greenhouse plant. Seeds are squirted from the ripe fruit in a jet of liquid.

Elettaria cardamomum (Cardamom) ZINGIBERACEAE (the ginger family) India

Perhaps not a very exciting plant to look at with its tufts of mid-green leaves but well worth growing. It is tough and was once known as the saloon plant, for it appeared to be able to survive on a diet of beer dregs and cigarette ends. Its leaves are aromatic; it is related to ginger; and its seeds provide the eastern spice, cardamom, which amongst other uses is included in curry powders. Its growth is like that of ginger with stems bearing two opposite rows of leaves arising from the fleshy rhizomes. Propagation by division of the rhizomes.

Eucalyptus globulus (Blue gum) MYRTACEAE Australia
This is easily grown from seed and has aromatic foliage from which eucalyptus oil may be extracted.

Fatshedera lizei ARALIACEAE Hybrid raised in France
An easily grown plant (see figure 58) with lobed ivy-like leaves arising from upright stems. It is unusual in being a hybrid between plants of different genera, namely, *Fatsia japonica* from Japan (q.v.) and *Hedera helix* from Europe (q.v.). It is more or less intermediate between its parents in appearance. It is easy to grow and has a quiet elegance. There is a variety, *Fatshedera lizei variegata*, which has attractive creamy white markings on the edges of the leaves. It is brighter than *F. lizei* but more difficult to grow well, for in a dry atmosphere the edges of the leaves dry up and turn brown. Propagated by cuttings, which are rather slow to root. It is a good plant to propagate by air layering when it gets long and 'leggy' through losing its lower leaves.

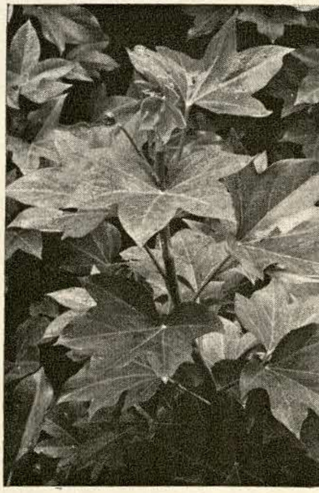


Fig. 58. *Fatshedera lizei*. Photo, H. Smith.

Fatsia japonica (Japanese aralia) ARALIACEAE Japan
This can be grown from seed.

Ficus elastica decora (India rubber plant) MORACEAE India
This plant, with its large leathery dark green oval leaves, is probably the best known of all house plants. It belongs to the mulberry family which also includes the fig. Another relative is the banyan tree, *Ficus benghalensis*. It yields a rubber, caoutchouc, and any incision in leaves or stem will cause a white latex to appear, but it is not the plantation rubber of Ceylon and Malaya; that is *Hevea brasiliensis*. The leaves last on the plant for years, so it is important not to allow them to become damaged or the plant will be permanently disfigured. Each new leaf arises in a bright pink sheath which splits and falls off to allow the young leaf to emerge. The roots can easily rot if the plant is over-watered, so the soil should be allowed to become dry before watering. High temperatures are needed for propagation but plants which have grown tall and lanky may be air-layered. If this is successful the old plant will probably send out one or two side shoots after the layered top has been removed, and these, too, may be air-layered to provide new plants.

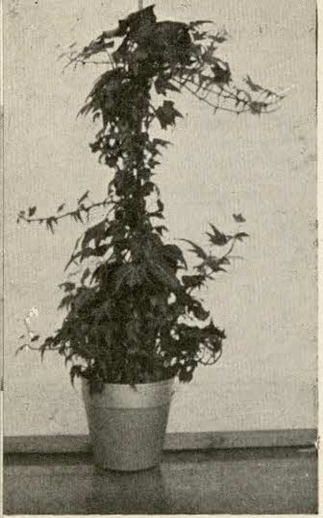


Fig. 59. *Hedera helix* (Green Ripple).

Ficus rubiginosa (*australis*) MORACEAE Australia
This is a more modest plant with laurel-like shiny leaves, and although it is not often seen it seems to stand up to classroom conditions very well.

Hedera helix (Ivy) ARALIACEAE Europe
This is the common ivy, and several varieties have been selected as attractive and hardy house plants. These are dwarf growing kinds most of which have prettily variegated or delicately divided foliage. They may be trained up over trellises or stakes, or allowed to trail down.

Some of the variegated forms tend to lose their colour in dull light and the leaves become almost plain green. These kinds must be kept near a window. Those forms which have greyish green variegated leaves do not seem to be liable to fade. Glacier is a good variety of this type. Of the plain green kinds *Sagittifolia* and Green Ripple (figure 59) are good.

Propagate *Hedera helix* by leaf bud cuttings, which may be slow to root but which are not otherwise difficult.

Hedera canariensis, the Canary Island ivy, is a larger-leaved species from North Africa and the Canary Islands. The variety, *variegata*, is one of the most attractive of house plants with its boldly marked dark green and white foliage. It sometimes produces spindly shoots with widely separated leaves and these are best removed. It is very susceptible to aphids and a single greenfly on the back of a leaf can cause it to become cupped and distorted.

Helxine soleirolii URTICACEAE Corsica
A soft, mossy plant pleasant to touch. This appeals to young children.

Monstera deliciosa (Mexican breadfruit) ARACEAE Mexico
One of the most imposing of indoor plants with its large, curiously divided leaves. (See figure 60.) It is a liane, and characteristic of these plants which make the tropical rain forests so difficult to penetrate, for it scrambles up the trees and sends down masses of thick rope-like roots to the ground. These roots are produced on a pot plant and though they are hardly beautiful they add to its interest and character. *Monstera deliciosa* is best in a trough or tub where it can spread its roots. As its name suggests, it has edible fruits, said to taste like a mixture of pineapple and banana, and though these may be produced in this country, they do not ripen. Propagation by the usual methods requires a good deal of heat but if the

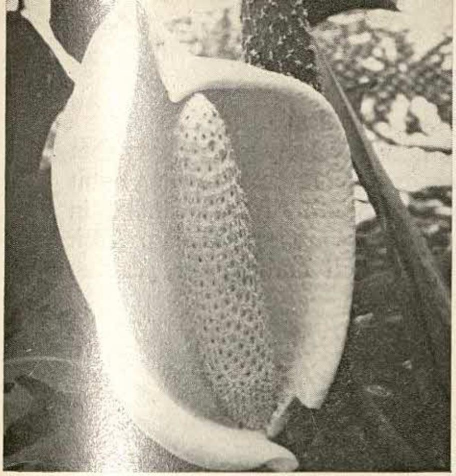


Fig. 60. *Monstera deliciosa* in flower. Photo, H. Smith.

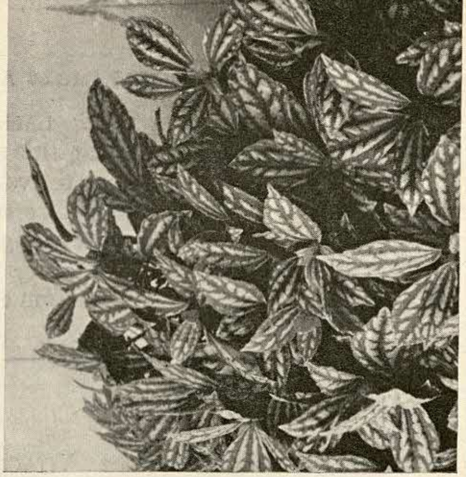


Fig. 61. *Pilea cadierei nana*. Photo, H. Smith.

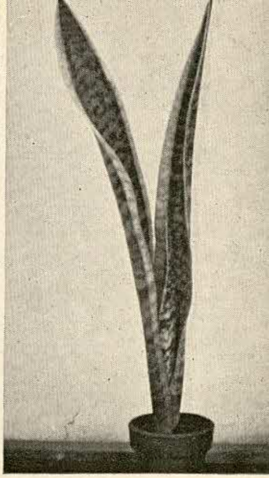


Fig. 62. *Sansevieria trifasciata laurentii.*

stem of a plant is laid along the soil and allowed to root into it, it can be cut up to give new plants. Each piece must contain a leaf or leaf base, from the axil of which a new shoot will appear.

Neanthe bella PALMACEAE Guatemala
A dwarf palm only a foot or so high, whose main merit is that it allows a representative of the palms to be kept in a small space. It has the long divided leaves so characteristic of its family.

Pilea cadierei (Aluminium plant) URTICACEAE Indo-China
An attractive little plant (figure 61) which looks as though its leaves have been painted with aluminium paint. It is easy to grow, roots easily from softwood cuttings, and is useful for general arrangements and bottle gardens.

Peperomia magnoliaefolia variegata PIPERACEAE S. America
A number of peperomia varieties are on sale as house plants and all have very attractive foliage, but most of them are difficult to keep for long periods. This species has very thick, waxy looking leaves of pale green heavily marked with cream. One of the main features of interest in the peperomias is that they are propagated from leaf cuttings, a single leaf giving rise to a new plant. Strangely, this variety gives only plain green leaves when propagated in this way, though there is a form, Green Gold, which produces variegated plants from leaf cuttings. To preserve its colour, *variegata* must be grown from ordinary stem cuttings.

Plectranthus oertendahlii Labiatae Tropical Africa

A pleasant if unspectacular little plant with velvety green leaves that have paler markings along the veins. It has a rather sprawling habit of growth. *Plectranthus fruticosus* from South Africa is similar in general appearance but the pale green leaves are less pleasing. Both plants root easily from cuttings and this, if nothing else, justifies their presence in the classroom collection.

Pteris cretica

(See 'Ferns', page 213.)

Rhoicissus rhomboidea Vitaceae Natal

Another vine, with a more delicate appearance than *Cissus*, the leaves being divided into three roughly rhomboidal leaflets. The buds and young stems are covered with silky hairs. It is easily grown and an attractive climber. Propagate by cuttings or leaf bud cuttings, both of which are rather slow to root.

Sansevieria trifasciata laurentii (Mother-in-law's sharp tongue, bowstring hemp) Liliaceae Tropical W. Africa

A striking plant (figure 62) with long, sword-shaped vertical leaves which are dark green and edged with a broad creamy yellow band. A related species is cultivated for the fibre in the leaves. The plant is rather fleshy and though it will stand a great deal of neglect in the form of underwatering it can easily be killed by too much water. During the winter it is wise to give it only enough water to prevent the leaves from shrivelling. Propagation is by division.

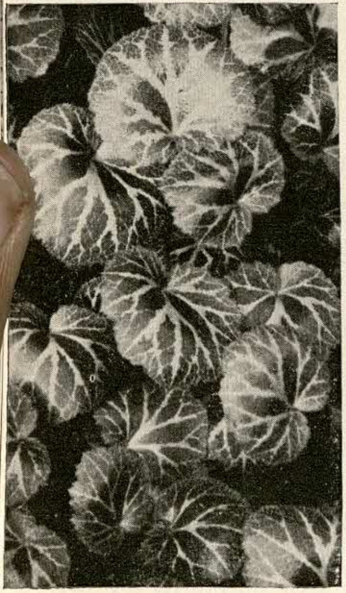


Fig. 63. *Saxifraga sarmentosa.* Photo, H. Smith.

Saxifraga sarmentosa (Mother of thousands) Saxifragaceae Asia

This plant (figure 63) has rounded dark green leaves with silvery markings along the veins, and purplish undersides. It produces feathery panicles of whitish flowers which are not particularly showy. Its main attraction lies in the masses of young plants which hang on thread-like runners from the parent plant. These runners hang almost like a curtain from a well grown plant and certainly justify its name, mother of thousands. They are very delicate and the slightest knock will damage them. For this reason and to display the runners at their best you should hang up or put the pot on a high shelf if possible, not forgetting, however, that the watering of plants in these positions is inconvenient and tends to get neglected. Propagation is by means of the young plants on the runners.

Tolmiea menziesii (Pick-a-back plant) SAXIFRAGACEAE N.Africa
A rather plain-looking plant, worth growing for the young plants borne at the base of the leaves. It is equally at home indoors or outside. Propagate this by detaching leaves bearing sizeable young plants and pressing them gently into the soil.

Tradescantia fluminensis (Wandering Jew, wandering sailor) COMMELINACEAE S. Africa
A very familiar and easily grown trailing plant, available in white, yellow, and pink-and-white variegated forms. It easily becomes scraggy and threadbare in appearance. When this happens cuttings should be taken and a new start made. It is difficult to get a good plant from a single cutting and usually five or six cuttings are put round the edge of a 3 in. or 3½ in. pot and grown as a single plant. The cuttings root very easily in water or any propagating compost. When pure green shoots appear on any variegated plant such as this they should be removed while still small because they grow vigorously and may become the dominant colour. (It is interesting to compare the rates of growth of the green with the variegated form.)

John Tradescant, after whom this plant was named, was gardener to King Charles I.

Zebrina pendula COMMELINACEAE Mexico
This is like a robust *Tradescantia* with leaves of purple striped with silver. It does not produce plain green shoots which so often spoil *Tradescantia*. It should be treated similarly.

FLOWERING POT PLANTS

A few kinds of flowering pot plants are amenable to classroom conditions if they are given a place near a window. The most reliable of these are:

Begonia semperflorens (Begonia) BEGONIACEAE Brazil
The small flowered bedding begonia is a most reliable plant. With a little care it will thrive and flower well in the classroom. It is well named, for it is almost perpetually in flower. It roots very well when grown from cuttings and will provide good material for this purpose. The seed is minute yet not difficult to grow, provided that it is never allowed to become dry.

Impatiens balsamina (Busy Lizzy) and *Impatiens holstii*

BALSAMINACEAE Tropical E. Africa

These are familiar plants with watery-looking stems and smallish mid-green leaves. The flowers are white, pink, orange, or various shades of red, and appear over a very long season. The ripe seed pods split open at the slightest touch and fling the seeds some distance away from the parent plant. There are several native or naturalized species which are usually found growing near water.

Propagation is by seeds or by cuttings, which root easily in water.

Pelargonium zonale (Zonal pelargonium) GERANIACEAE

S. Africa

This is the plant with a scarlet flower, familiarly but incorrectly known as a geranium. It can be grown well as a room plant but seldom is. It is adapted to growth in the brilliant light of its native South Africa and will become pale and spindly unless given a place in a sunny window. There is a huge number of varieties on the market. The new Irene varieties are compact and flower for a long time, and are well worth trying. Propagate it by cuttings. These are often left on a shelf for a few days before planting, so that the cut end dries out and forms a protective skin. This reduces rotting.

The varieties listed below have scented leaves. They are very tough plants in the main and will stand a good deal of dryness and neglect, provided that they are not over-watered. Flowers are usually rather insignificant.

Crispum:	Small green leaves, lemon-scented
Crispum variegatum:	Silver variegated and very attractive leaves, lemon-scented
Lady Plymouth:	Variegated, with sweetish peppermint scent
Tomentosum:	Peppermint-scented

BULBS

Apart from their beauty, bulbs are valuable in the classroom because they allow us to follow the life cycle of a plant reasonably quickly. This can be done in winter, when few other plants are in active growth.

A bulb is essentially a large bud, the scales of which are thick and fleshy and packed with stored food. This enables the plant to grow and flower quickly before unfavourable conditions set in. Thus, bluebells in an English wood flower before the leaves of the trees cut out the light, while in the dry lands of the Near and Middle East, which are so rich in bulbous plants, the plant completes its growth before the onset of the summer drought.

The term bulb is applied loosely in horticulture to cover organs which are corms and tubers as well. The crocus 'bulb' for example, lacks the layered structure of a true bulb and is really a thickened stem—a corm.

There is no need to grow bulbs in special bulb fibre. The sand and peat compost suggested earlier is perfectly satisfactory. There is not even any need to feed the bulbs in this case, since they contain all the food needed for early growth and flowering. After flowering, if the bulbs are not to be thrown away, they must be fed so that they can build up reserves for next year's flowering. Since they will rarely succeed indoors for a second year it is best after flowering to plant the complete clump in a border outside. Bulbs are grown outside in tubs or window boxes and will flower year after year only if they are grown in a good compost such as John Innes Potting Compost. Whatever course is followed, bulbs cannot build up stores for the following year unless they are watered and tended until the foliage dies down naturally.

Containers

Clay and plastic flower pots and pans as suggested earlier are satisfactory and have an advantage over bulb bowls in that they have drainage holes, so there is less danger of waterlogging.

Planting

Crocus corms, being broad and flat, may just be pressed into the compost. With other corms or bulbs, compost should be put into the pot and gently pressed firm so that when they are planted their noses will be above the ultimate soil level. Further compost should be added and made firm around them until the soil is ½-1 in. below the rim of the container. Some of the larger bulbs make such vigorous root growth that they force themselves out of the pot if they do not have sufficient soil packed around them in this way. No watering is necessary at this stage if the compost is properly moist. To ensure a good show, plant the bulbs quite close together —about ½ in. apart and ½ in. from the edge of the pot.

It is not necessary to put the bulbs in a dark place after planting. Indeed, doing this often means that a classroom cupboard or similar place is used which is not only dark but warm. This leads to failure because it is cool conditions rather than darkness that are required.

Commercial bulb growers usually plant their bulbs in boxes in the open and cover them with 6 in. of straw to keep out severe frost. If this can be done in school, well and good. Sand or ashes 3-4 in. deep may replace the straw. If a garden frame is available for the bulbs no covering is necessary, but a watch must be kept for slug damage. Mice, too, may be troublesome: they are especially fond of crocuses. Whatever provision is made, it is essential to plant the bulbs soon after they arrive and keep them in a cool place for six or eight weeks.

Bulbs planted in October should be well rooted and ready for bringing inside early in the spring term. It is a good rule to wait until the flower bud is through the neck of the bulb. This may be a matter of judgment. Buds of hyacinth, crocus, scilla are easy to see; the leaves of daffodils and narcissus may be parted gently to reveal the bud. Most bulbs will be in this state by the time the shoots are about 2 in. high.

One of the commonest causes of failure is not giving the bulbs time to develop roots and flower buds in cool conditions. In either case the result may be vigorous leaves hiding the flowers, and poor stunted flowers. Another cause of failure is forcing in too high a temperature. If classrooms are hot—about, say 18°C—bulbs may be better in cooler corridors. Even those flowers which develop well in heat will only last a short time in high temperatures. The pots of bulbs should never be allowed to dry out for bulb roots are soft and fleshy and easily damaged. Some bulbs, such as the narcissi Paper White, Soleil d'Or, and Cragford, grow well in bowls of small pebbles filled with water to about an inch below the bulbs. Hyacinths grown in water are familiar enough and are useful for observations on root growth and to explode the myth that shoots grow towards the light and roots away from it. Onions, too, are often grown in this way. The main condition for success is to keep the water level only a few millimetres below the base of the bulb. Daffodils and tulips, amongst the bulbs most commonly grown in the classroom, are relatively difficult to grow. Since they are also among the more expensive, some of the smaller and cheaper bulbs are worth considering.

It should be possible to get one hundred of these smaller bulbs for little more than the cost of a dozen daffodils or tulips, especially since wholesale rates are applicable for quantities of one hundred.

Some smaller bulbs for indoor cultivation

Chionodoxa luciliae (Glory of the snows) LILIACEAE Near East
Each bulb produces several brilliant blue flowers about 1 in. across with white centres.

Crocus vernus (Dutch crocus) IRIDACEAE Europe
These are the large garden varieties. The purple, white, and striped varieties are excellent, but in our experience, the yellow ones are extremely difficult to grow indoors and are unlikely to flower well. We are not sure of the reason for this.

Crocus chrysanthus IRIDACEAE Greece, Turkey
This includes Blue Bird (blue, edged white), Blue Giant (soft blue), Cream Beauty (cream), Zwanenburg Bronze (deep yellow with blackish bronze markings). There are many crocus species on the market, most of which are worth a trial. *Chrysanthus* is one of the best, and many beautiful varieties of it have been produced, giving a range of colour unobtainable in the Dutch crocus. The varieties are smaller than the Dutch, they often flower earlier and more freely, and the flowers open wide. They are best in cool conditions, and although they will develop remarkably in a hot room, they are soon over.

The structure of these flowers is remarkable, for what appears to be the flower stalk is part of the flower, and the style can be traced down it to the ovary, which is just above the corm. Another feature of interest is the speed with which the flowers can sometimes be persuaded to open if they are put in a hot place. Sometimes it is actually possible to see the petals move.

Galanthus elwesii and *Galanthus nivalis* (Snowdrop)
AMARYLLIDACEAE Europe and Asia
Nivalis is familiar and easy to grow, but indoors it must be given a cool place. *Elwesii* is a larger kind of snowdrop which is cheap and easy to get.

Iris reticulata IRIDACEAE Northern Persia, Caucasus
A wonderful little iris, 6 in. high with purple-scented flowers.

Muscari armeniacum and *Muscari botryoides* (Grape hyacinth)
LILIACEAE Turkey, S. Europe
These are easily grown so long as they are not forced.

Narcissus minimus AMARYLLIDACEAE Europe
There are many kinds of dwarf *Narcissi*, but they are not particularly suitable for classrooms and few of them are cheap. This one, the smallest, would delight any child, for it is a tiny trumpet daffodil about 4 in. high.

Puschkinia libanotica LILIACEAE Turkey to Afghanistan
Bluish-white wide open flowers with a pale blue stripe down the middle of each petal.

Scilla bifolia LILIACEAE Mediterranean
Blue starry flowers.

Scilla sibirica (Siberian squill) LILIACEAE Russia
Brilliant blue drooping flowers. Spring Beauty is a larger variety of this species, but more expensive.

Some larger bulbs for indoor cultivation

Of the larger bulbs the following are a few good varieties:

Narcissus (Narcissus, daffodil) AMARYLLIDACEAE

Carbineer	Large yellow perianth with orange cup
Carlton	Large yellow perianth and cup
Dutch Master	Yellow trumpet
Flower Record	Large white perianth with orange cup
Geranium	Bunch flowered, white perianth, orange cup
Golden Harvest	Yellow trumpet
La Riante	Small white perianth, with deep orange cup
Rembrandt	Yellow trumpet
Texas	Double, yellow intermixed with orange
Verger	Small white perianth, with deep orange cup

There is often confusion over the names daffodil and narcissus. Both are, botanically, *Narcissi*, but the common name, daffodil, is used for those *Narcissi* with trumpets as long or longer than the perianth segments.

Hyacinthus (Hyacinth) LILIACEAE
Most of these are suitable for the classroom.

Tulipa (Tulip) LILIACEAE
Tulips are not easy to grow indoors. It is particularly important to

provide a cool rooting period, not bring the plants indoors too soon, and not put them in a hot room.

Early Single	
De Wet	Orange
General Joffre	Yellow
Proserpine	Pink
Vermilion Brilliant	Scarlet
Early Double	
All Gold	Yellow
Niels Finsen	Rose
Orange Nassau	Deep Orange
Schoonoord	White

There are many lovely, dwarf species tulips, but few do well inside. *Tulipa Fosteriana Madame Lefebvre*, which has spectacular huge scarlet flowers that open wide to reveal a yellow-ringed black centre, can be grown successfully as a pot plant.

CACTI AND OTHER SUCCULENTS

Succulents are plants mainly of the hot and arid regions. Their tissues are swollen with stored water. Cacti are succulents belonging to a particular family—the Cactaceae—which, in the wild, is almost completely confined to the warmer parts of America. In colloquial gardening language, the term 'succulents' refers to those other than cacti, a large and varied assembly of plants particularly well represented in the flora of southern Africa. The great range of form of cacti and other succulents, ranging from the beautiful to the grotesque, makes them interesting to children. Since they are available in considerable variety in tiny 'thimble' pots at around 1s 6d to 2s 6d, some children make their own collections. While there is little merit in keeping the indestructible old monster, which survives, ignored and neglected, at the back of the nature table, there is plenty of interest to be derived from a collection chosen for variety of form, interesting propagation, and beauty of flower.

These plants look better and usually grow better if they are grouped together to form a 'desert garden'. This may be made in any suitable shallow container, ranging from a seed pan to a kipper or tomato box (suitably disguised!). The container should be filled with sandy soil, and the specimens can be arranged and planted in this, perhaps with pieces of rock outcropping to give a more interesting effect. Particular care is needed to see that they are not planted deeper than in their original pots, or rotting may occur. The surface can be covered with sand or gravel to give a good finish and to prevent moisture collecting round the necks of the plants, since this causes rotting. In nature, the roots of these plants are often shallow and wide-spreading. This method of planting allows them to grow naturally, and often produces better plants. If the plants are to be rearranged from time to time they may be left in their pots and plunged in the compost with the rims just hidden. The more vigorous growers may grow roots through the drainage and establish themselves in the compost, but others can be moved around freely.

Cacti and succulents withstand a lot of neglect in watering, as one would expect from the climate of their native habitats. Many will tolerate low temperatures provided that the soil is dry, but it is best to keep them in a warm place if possible. During the winter they need a minimum of water—an occasional sprinkle with tepid water to prevent shrivelling is enough. In hot sunny weather they will appreciate a good watering like any other plants, provided that the soil is porous so that surplus water may drain away quickly and provided that the soil is not continually wet.

The plants offered so widely in the shops are usually easy to grow, or they would not be so cheap, and the best way of making a classroom collection is usually to buy locally and pick out those kinds that appeal.

Some easily grown succulents of interest are:

Aeonium domesticum CRASSULACEAE Madeira and Canary Isles

Agave americana (Century plant) AMARYLLIDACEAE
Central and S. America

This has spiky rosettes which can become very large. Propagate it by offsets.

Aloe variegata (Partridge plant) LILIACEAE South Africa
Propagate this by offsets.

Echeveria CRASSULACEAE Central America
Attractive succulent rosettes, Propagated by offsets or leaves.

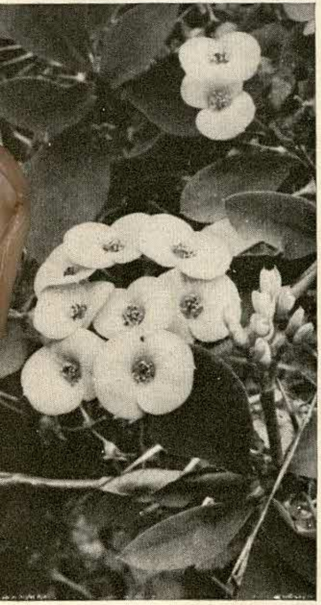


Fig. 64. *Euphorbia splendens*. Photo, H. Smith.

Euphorbia splendens (Crown of thorns) EUPHORBIACEAE
Madagascar

A viciously spiny shrubby plant (figure 64) which carries bright scarlet flowers over a long period. A relative of the native spurges, which have yellowish green flowers. (In both cases the 'petals' are bracts—modified leaves, not petals.)

Kalanchoe blossfeldiana CRASSULACEAE Africa and Far East
Scarlet flowers. Often sold as a flowering pot plant. Can be grown from seed.

Kalanchoe daigremontiana CRASSULACEAE South Africa
In this plant the plantlets are all round the edge of the leaves and look very impressive. The slightest touch dislodges them, however.

Kalanchoe verticillata CRASSULACEAE South Africa
Carries tiny plants on the ends of the narrowly cylindrical leaves. These soon grow into new plants if laid on moist soil.

Kleinia articulata (Candle plant) COMPOSITAE S. Africa
Propagated from cuttings.

Oliveranthus elegans CRASSULACEAE Mexico
This has showy scarlet flowers.

Pteris cretica POLYPODIACEAE
See 'Ferns', page 213.

Sedum (Stonecrop) CRASSULACEAE
Many are hardy. Some tender kinds are excellent pot plants. *Sedum sieboldii variegatum* has very pretty blue-green and cream leaves. Propagated by cuttings, or, with some kinds, leaves.

Sempervivum (Houseleek) CRASSULACEAE Asia and Europe
Mostly hardy and very easy to grow. Fleshy rosettes. *Sempervivum tectorum* is the common houseleek. *Sempervivum arachnoideum* is the cobweb houseleek. It looks as though each rosette is covered in cobwebs.

Cacti in one group, which includes *Zygocactus truncatus*, the Christmas cactus, *Schlumbergera gaertnerii*, the Easter cactus, and the *Epiphyllum*—all plants with flattened leaf-like stems—are not desert plants but grow on trees or rocks in moist tropical forests. The Christmas cactus produces numbers of pendant purple flowers in midwinter, the Easter cactus has scarlet flowers in spring, and the *Epiphyllum* varieties have large flowers like a water lily, many different colours. All these plants need a porous compost with plenty of humus in it. Though they are not desert plants, they must still be watered carefully, especially in winter. They should be given a partially shaded position.

PLANTS OF ECONOMIC AND SOCIAL VALUE

1. *Food and drink*

Seeds from fruits which children have eaten and from other home sources are worth growing for their particular relevance and interest. Amongst them are:

Apple
Blackcurrant
Cherry
Date
Gooseberry
Grape
Grapefruit
Lemon
Marrow
Melon
Orange
Peach
Pear
Plum
Pomegranate
Raspberry
Redcurrant
Strawberry
Tomato

Some, notably the stone fruits, will grow better if the pots in which they are sown are placed outside during the winter. Most of them will not survive for long in the classroom although, strangely, the more exotic plants—the citrus fruits, date, and pomegranate—are the most likely to be successful. The hardy ones will make an interesting collection in the school garden if there is one.

Peanuts are reasonably easy to grow, though they will not crop. Cereals—wheat, oats, barley, maize—could also be tried, and children might ask 'Why can't we get rice to grow?' (We can, of course, if we use brown rice.) Mixed birdseed would also be interesting. These are only likely to mature outside, but if there is no garden to put them in, at least the early stages can be seen. (How can we distinguish between the common cereals when they are only a few inches high?)

Mustard (and cress) if allowed to continue growth until they are mature, will yield seeds for a new crop, especially if they are planted out of doors.

Carrot tops are often grown in a saucer of water—why not parsnips, or turnips, for comparison?

Potatoes offer plenty of opportunity for experiments, for example, on the following questions:

What is the difference between sprouts grown in the dark and in the light?

Can we cut up the potato and get several plants?

Can we pull off individual shoots to get separate plants?

Can we peel a potato and get the eyes to sprout and give us new plants, while leaving the inside for food? (Wartime research was carried out to test whether this could be done on a large scale.)

Where on the tuber do the sprouts come from?

Potatoes can be sprouted dry, as they naturally would if they were left in the bag, or they may be planted in compost or peat. Their sprouts sometimes provide valuable crops of greenfly for further studies.

Peas and beans are often the only seeds grown in the classroom, although plenty of others deserve a place since we should try to bring children into contact with as large a variety of living things as possible. Grass, for example, is one of the most important plants in the world. Surely it deserves a place. Miniature gardens can be made from seed sown in a seed tray or kipper box. Perhaps grass seed can be broadcast to form a 'lawn', while vegetable seeds can be sown in rows. Why is the grass seed broadcast? Why are vegetable seeds sown in rows?

For convenience, we may group the commonest plants that provide us with food and drink according to the part which we use. For example:

Buds	Asparagus (of which we also eat the stem), Brussels sprouts, cabbage, and lettuce (the last two are really huge buds, although we are apt to think of them as leaves)
Flower buds	Cauliflower, globe artichoke
Flowers	Crystallized rose petals and violets
Fruits	Cucumber, French bean, marrow, runner bean, tomato, as well as the dessert fruits (see page 268) and barley, maize, oats, rice, wheat, and other cereals
Leaf stalks	Celery, rhubarb
Leaves	Spinach, tea, etc.
Roots	Carrot, parsnip, sugar from sugar beet
Seeds	Broad beans, cocoa, coffee, haricot beans, nuts, peas
Stems	Potato (an underground stem, not a root), sugar from sugar cane

The immense importance of seeds and fruits for food is worth special note. They contain food in concentrated form and are easily stored and transported. They also provide most of the vegetable oil which goes to make margarine and cooking fat.

Fungi also play their part in our food supplies. In addition to the obvious case of mushrooms and to the moulds which flavour cheeses such as Gorgonzola and Camembert, yeast holds a unique position

(*a*) in leavening bread;

(*b*) in producing alcoholic beverages.

Seaweeds have long been eaten in coastal areas, but recently they have assumed a much wider importance in the form of alginates

which are used to give body to a variety of foods such as dried so
artificial cream, and instant sweet dishes.

Here are some sources of spices and flavourings:

Bark	Cinnamon
Flower buds	Cloves
Fruit	Oil of lemon
Leaves	Mint, sage, thyme
Root	Liquorice
Seed pods	Vanilla
Seeds	Aniseed, caraway, mustard, nutmeg, pepper, e
Stem	Ginger—even root ginger is an underground ste

2. *Drugs*

Eucalyptus, foxglove, opium poppy, quinine, and hosts of ot
plants have been used in medicine. Many are still important. T
number that have been superseded by synthetic drugs are m
than outweighed by antibiotics such as penicillin, made from fu

3. *Clothing and other fibres*

Coal	Nylon and other synthetic fibres
Seed hairs	Cotton, kapok
Stem fibres	Flax, sisal, manila hemp, hemp for twine an ropes, jute for string and sacks, carpet and linoleum backing
Wood	Rayon

4. *Fuel*

Wood, peat, coal, oil—at least partly formed from fossil plants.

5. *Structural materials*

Woods of various kinds for buildings, fences, jetties, railway lines, and telegraph poles, as well as furniture. Bamboo is, of course, vital for these purposes in the economies of many tropical peoples.

6. *Rubber*

In spite of synthetic substitutes, natural rubber from various latex-producing plants is still important. It is interesting to note that the latex with which children are familiar, such as that in poppies and dandelions, is similar to that of the rubber tree, and in fact one sort of dandelion is grown on a large scale in Russia to produce rubber.

7. *Perfumes*

Considerable acreages in various parts of the world are devoted to growing plants such as roses and lavender for perfume.

8. *Dyes*

While dyes such as woad, indigo, and saffron are no longer important items of commerce, we must not overlook their importance up till quite recently. Indeed, there is still considerable interest in the small-scale use of vegetable dyes. Some, such as turmeric, are still used in colouring foodstuffs, while litmus, made from a lichen, is still a familiar chemical indicator.

9. *Other economic benefits*

It would be possible to list many other categories of commercial products that come from plants—insecticides such as Derris and pyrethrum, oils and waxes such as linseed oil for paints and carnauba wax for polishes, tannins from tree barks for tanning leather, gums and resins from various trees and shrubs, cork from the cork oak, etc.

In addition to producing an immense range of commercial products, plants perform a tremendously important service in stabilizing soil. In this country marram grass is used to bind the loose sand of seaside dunes, while cord grass, *Spartina townsendii*, performs a similar function on mud-flats. In either case these pioneer plants eventually stabilize the sand or mud so that firm land is formed. We are little troubled by soil erosion in Britain, but overseas the dust bowls and other erosion areas have shown the supreme importance of vegetation in preserving the precious soil cover.

10. *Some social benefits*

The beauty of the countryside depends largely on the vegetation cover, nowhere more so than in Britain, and where so much of the attraction of the scenery depends on trees and grass. Not only in the country but in the towns, plants, and particularly grass, are valuable in providing a setting to important buildings.

Gardening is the most popular hobby in the country. Most of our outdoor sports require turf, from the superb surface of the bowling green to the rough turf of the race-course. Children, too, use plants in their play, rolling on grass and climbing trees, making daisy chains, dandelion clocks, and rose-hip itching powder, throwing burrs, and shooting plantain heads.

One must also note the importance of plants in art and decoration. Flower arrangement is probably our most popular artistic hobby, and flowers, the grains of various woods, the texture of bamboo, raffia, and reed are used in decorating our homes. Curtains and other furnishing fabrics, dress material, carpets, wallpaper, and pottery all show that plant forms, more than any others, have given inspiration to their designers.

Plants grown mainly out of doors

ANNUALS

These grow and flower very quickly and children can put the complete life cycle into operation, from seed sowing to collecting the seed for the next year's show, in a few months. This will also involve them in comparing seedlings, the effects of thinning, the time taken to reach flowering stage, the lengths of flowering seasons, and the numbers of seed produced per pod and per plant, etc., and in cleaning and testing the collected seed. The following year's plants may not be true to type, showing perhaps a mixture of colours, and then there arises the questions of the role of bees and cross-pollination, and the ways in which the seed grower would maintain the purity of his stocks. Annuals may be sown in clumps to make an annual border or they may be used to fill up gaps between other plants. If the children want a border, they will need to plan carefully to achieve satisfying colour schemes and to calculate the cost of the project.

The following are easily grown annuals and although one or two are not very hardy, they all may be sown in the open ground in April.

Latin name	*Common name*	*Country of origin*
Brachycome	Swan River daisy	Australia
Calendula	Marigold	S. Europe
Centaurea cyanus (dwarf forms)	Cornflower	Europe (native to Britain)
Chrysanthemum segetum	Annual chrysanthemum	Europe (native to Britain)
Chrysanthemum tricolor	Annual chrysanthemum	N. Africa
Clarkia	Clarkia	California
Convolvulus tricolor	Bindweed	S. Europe

Cosmos	Mexican aster	Mexico
Echium		S. Europe
Eschscholtzia	Californian poppy	California
Gypsophila elegans		Caucasus
Helianthus annuus	Sunflower	Caucasus
Heracleum mantegazzianum	Cartwheel flower (a huge relative of hedge parsley —grows to twelve feet in a year!)	N. America
Iberis	Candytuft	S. Europe
Linaria maroccana	Toadflax	Morocco
Limnanthes	Poached eggs	N. W. America
Nigella	Love-in-a-mist	S. Europe
Papaver rhoeas	Shirley poppy	Europe (native to Britain)
Phacelia campanularia		California
Salvia horminium		S. E. Europe
Tropaeolum majus	Nasturtium	Peru

These are easy to grow and reliable. Even this small selection has representatives from five continents, but there are plenty more which are almost as easy to cultivate, especially in the southern half of the country, which would give scope for an interesting geographical border.

HERBACEOUS PERENNIALS

Although they will undoubtedly wish to encourage originality on the part of the pupils, teachers may find it convenient to have the following list of some of the plants of the traditional herbaceous border:

Achillea 'cerise queen'	A yarrow with deep red flowers. Compare with pinkish variations of the wild plant.
Achillea 'gold plate'	Flat yellow head. Can be dried for winter decoration.
Aquilegia	Columbine. Long spurs are nectaries. Try to distinguish sepals and petals.
Artemisia stelleriana	Dusty miller. Grown for its grey foliage. Aromatic leaves.
Dicentra spectabilis	Dutchman's breeches. A lovely plant with unusual flowers.

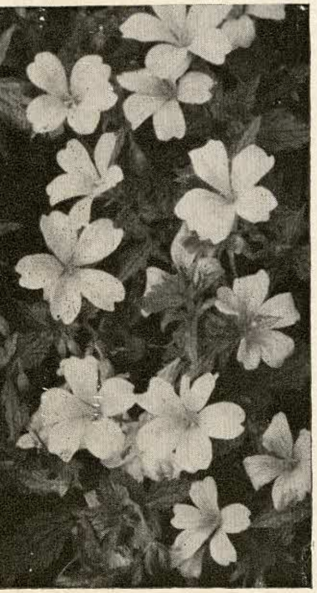


Fig. 65. *Geranium endressi.* Photo, H. Smith.

Echinops	Globe thistle. Root cuttings. Daisy family.
Eryngium	Sea holly. Root cuttings. Stems tinged blue.
Euphorbia epithymoides	Spurge. Unusual greenish flower heads. The 'petals' are bracts. Find the flowers.
Geranium endressi	A true geranium or cranesbill (figure 65), as distinct from pelargonium, the so-called scarlet geranium. Interesting seed catapults. There are many other good kinds, but this one flowers for a particularly long time.
Hemerocallis	Day lily.
Lupinus	Lupin. Interesting pollination. Watch the bees at work. Seed dispersal by explosive mechanism. Root nodules.
Mimulus luteus	Monkey flower. The stigmas are sensitive and can be seen to close as they are touched.
Monarda didyma	Bergamot. Aromatic foliage. Bumble bees can often be seen 'cheating' by biting the flower tube halfway along and so getting nectar without pollinating the flower.
Papaver orientale	Oriental poppy. Huge flowers, and huge seed heads which are useful for winter decoration. Root cuttings.
Phalaris arundinacea picta	Gardener's garters. Attractive grass with ornamental foliage.
Physalis franchettii	Chinese lantern. Inflated calyx for winter decoration.
Physostegia virginiana	Obedient plant. Flowers will stay in any position to which they are pushed.
Sedum spectabile	Stonecrop. Late flowers visited by many insects.
Tradescantia virginiana	Spiderwort. Very different from the indoor species, *fluminensis*.

This list omits many popular and easily obtained plants, which may well find a place in the primary school garden. It has been compiled to suggest some of the reasons, beside floral beauty, for choosing what plants to grow. A later list (page 279) suggests others of particular interest.

TREES AND SHRUBS

Where new schools are built on reasonably spacious sites there is usually room for some ornamental trees and shrubs. Unfortunately these are usually planted by the local authority Grounds Department with no reference to the school staff. The plants are selected because they are cheap, easily obtainable, and hardy, and because they make a fair show and take little looking after. They are seldom chosen for any educational interest they may possess. Indeed their season of beauty is very often of very short duration, as in the case of Japanese cherry, a quite frequent choice, which is magnificent for a fortnight and that possibly in the Easter holiday! We must try to persuade the administrators to be more enlightened in their choice. Perhaps the chief value of trees and shrubs in school is to create interest all round the year, particularly when the smaller plants have died down. Some are evergreen, some have attractive bark or berries, or colour well in autumn, while a few are double value plants with two seasons of beauty. For example, the fruiting crab apples have a show of flower in spring and a second show, this time of fruits, in autumn.

Here are some suitable trees and shrubs to grow:

	For coloured bark
Betula pendula	Silver birch. White trunk. Amongst the loveliest of all trees. Several suitable species.
Cornus alba	Dogwood. Red twigs. Westonbirt variety is particularly bright.
Rubus cockburnianus	A bramble with mauve-white stems.
Salix	Willow. *Salix matsudana* and its variety, *tortuosa* (figure 66), is a willow with every twig curiously twisted and contorted. There are varieties of hazel and false acacia with similar characteristics. *S. alba vitellina* has yellow twigs and *S. alba britzensis* has coppery scarlet twigs.

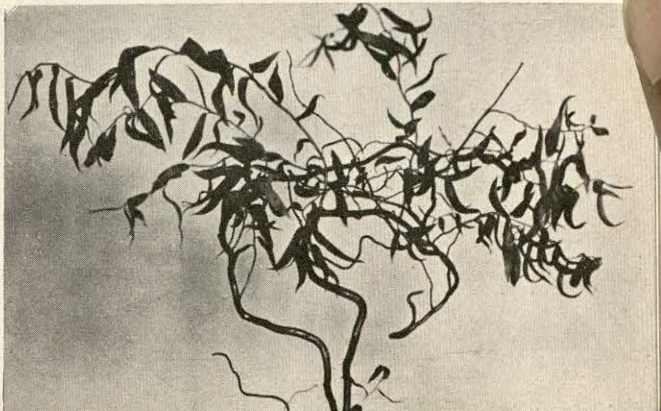


Fig. 66. *Salix matsudana tortuosa.*

For coloured fruit

Not all berries are red! It is interesting to make a collection of plants with variously coloured fruit.

Berberis	Barberry. Many varieties are excellent for berries. *Berberis aggregata, polyantha,* and *wilsonae* are three good kinds.
Callicarpa giraldiana	This has violet berries.
Cotoneaster	Good shrubs with scarlet berries. *Cotoneaster horizontalis* is the dwarf fishbone cotoneaster. *Cotoneaster simonsii, wardii, franchetii,* and *salicifolia* are good. *Cotoneaster frigida* and its hybrid *cornubia* will make small trees.
Malus	Crab apple. Many kinds are available. Good ones are John Downie (red and yellow fruit), golden hornet (yellow fruit), and *purpurea* (deep purple).
Pyracantha	Firethorn. Orange berries.
Rosa moyesii	A rose grown for its large red hips.
Sorbus	Mountain ash. Orange-red fruits. Variety *fructu-luteo* has yellow fruits. Others have white, pink, yellow-orange, or red fruits.
Symphoricarpos	Snowberry. White berries. New varieties range from pink to bright magenta.

For autumn leaves

Acer palmatum	Maple. Especially 'Osakazuki': good, but expensive.
Amelanchier canadensis	Snowy mespilus.
Berberis thunbergii	Japanese barberry.
Euonymus alatus	Spindle tree.
Rhus typhina	Sumach.

Note: Many cherries and crab apples colour well.

For coloured foliage

Acer negundo variegatum	Box elder. Green and white variegation.
Cornus alba elegantissima	Dogwood. Green and white variegation.

Ligustrum ovalifolium aureum	Golden privet. Yellow leaves.
Prunus pissardii	Purple leaved plum.
Santolina incana	Cotton lavender. Dwarf, grey.
Senecio laxifolius and *S. greyii*	Silvery leaves.
Weigela nana variegata	Bush honeysuckle. Green and yellow variegation. Pink flowers.

For winter flowers

Daphne mezereum	The well known Daphne with purple flowers. This is good, but has poisonous berries.
Erica carnea	Heather (white to purple). Lime-tolerant.
Erica darleyensis	Heather (rosy red).
Forsythia spectabilis	The best known winter flowering shrub; sprays of bright yellow flowers.
Hamamelis mollis	Witch hazel (yellow). This is expensive.
Jasminum nudiflorum	Winter jasmine (yellow).
Prunus subhirtella autumnalis	Cherry (pale pink).
Viburnum fragrans	Viburnum. (Pale pink, scented.)

Some possibilities for study with trees

Because of their size and permanence, trees are the most imposing of plants; the opportunities for learning are correspondingly great. These are some questions they may give rise to:

Can we determine the height?
By how many methods?
Can we determine the girth?
Can we determine the diameter?
Can we measure this directly? Is it possible to calculate it from the girth? Is there a constant proportion?
What is the spread of the branches? Is this equal on all sides? If not, can we find out why not?
Can we estimate how many seeds the tree bears? What happens to them? How far do they travel? In still air? In a wind? Can we get them to grow?
How much timber might the tree yield? What would it be used for? What kinds of timber are used in school? How can we

> recognize them? Which is the strongest? Which the most pliant? What does the grain represent? The knots?

It may be possible to find a tree stump, or perhaps a sawmill will supply a slice from the base of a log. These questions may result:

> What do the rings represent? How old was the tree when it was cut down? Which rings were laid down in the years when the children in the class were born? When their fathers were born? Their grandfathers? Can the class make a chart showing important events occurring when the various rings were formed?

If the end grain in various wooden articles of furniture is visible it will be possible to find out how many years' growth went to make up the wood. These questions may follow:

> What precaution must we take in trying to work this out from side grain?
>
> What creatures attack the tree? Which creatures seek shelter in it?

Finally, children may observe leaves, twigs, bark, trunk, branching, flowers, fruit, etc. They will enjoy making a calendar of the tree's year, from bud burst to leaf fall.

Forest trees

The scope of tree studies in school can be extended considerably if a corner of the garden is set aside as a forestry plot. Children may be able to gather seeds of the common trees such as oak, ash, birch, beech, horse chestnut, and sycamore, and if these are sown as soon as possible after gathering, a reasonable germination should be obtained. Seeds of conifers will probably be more difficult to find, but they are available from some seedsmen. Alternatively, it may be possible to persuade a local forester to part with a few. Where a bought packet contains only a few smallish seeds, as may be the case with the cypresses, for example, it would be wise to sow them in a pot or box, covered with a sheet of glass, so that they can be given more attention.

It will not be possible to raise willows and poplars from seed, but these root very easily from cuttings and grow fast.

A few nurserymen stock small plants of forestry trees and offer them simply at very reasonable prices, though most forestry nurseries sell them only by the thousand. The Forestry Commission is very helpful and is prepared to allow a hundred small trees to any school which is sufficiently interested to plant and care for them. It is most sympathetic towards schools. If there is a forest nursery within reach a visit would be well worth while. There is a scheme for schools to adopt small areas of their local forests. Though this is generally more suited to secondary schools, there may be some possibility of younger children being able to profit from it in some areas. The Commission's booklets, *Starting a School Forest* and *Forestry in the Town School* are issued free and are well worth having.

If the children have raised too many trees for the school forestry plot, they might plant them round the playing field. Alternatively, perhaps they could find somewhere in the neighbourhood to transfer them, to give pleasure to the whole community. If we can interest our children in their surroundings in this way we shall be making a positive contribution to preventing vandalism.

If there is space to grow a few trees, then the Norway spruce—the Christmas tree—should certainly be included among them so that the children may have the joy of growing Christmas trees for their own classrooms. Since this tree can be lifted with most of its roots, it can be put back in the plot after its term in the classroom.

The following is a list of conifers used in forestry in this country, which might find a place in the plot.

	Wood
Norway spruce (Christmas tree)	White deal
Sitka spruce	White deal
European, Japanese, or hybrid larch (examples of deciduous conifer)	
Thuja plicata (giant arborvitae)	Western red cedar
Douglas fir	Oregon pine
Scots pine	Yellow deal
Lawson's cypress	

Even where there is no school garden it may be possible to grow a few of these trees in tubs or even in pots in the classroom. The very restricted rooting space keeps the trees small and they may survive for many years, as is the case with the dwarf trees produced by the Japanese.

PLANTS OF SPECIAL INTEREST

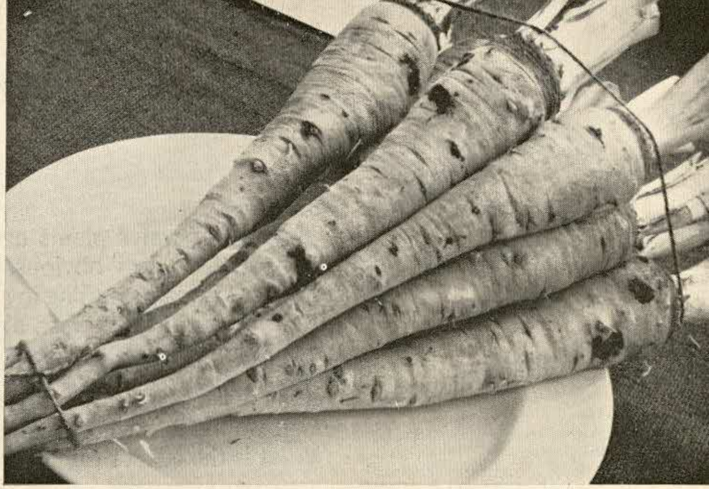
There are many plants which would be worth a place in the school garden because of their interesting characteristics or associations. Amongst them are such plants as:

Betula papyrifera	The paper bark birch. Used by the Red Indians for writing material and for making canoes.

Cedrus libani	Cedar of Lebanon, used for building the Temple.
Cercis siliquastrum	Judas tree. The tree from which Judas is supposed to have hanged himself. Attractive rose-purple flowers grow direct from the branches, even from the trunk.
Cucurbita pepo	Produces an ornamental gourd. Can be used for craftwork. There are other plants producing gourds in a variety of interesting shapes and colours which are also of interest for the school garden.
Dipsacus fullonum	Fuller's teasel. Formerly used to put the nap on blankets. Dried heads make excellent winter decorations.
Helichrysum bracteatum	Everlasting flower. Easily grown from seed. So are other everlastings, including *Acroclinium* and *Rhodanthe*.
Impatiens royleii	Himalayan balsam, now becoming naturalized in many places. Ripe seed pods explode when touched.
Isatis tinctoria	Woad.
Morus alba	White mulberry. Food for silkworms.
Onopordum acanthium	The Scotch thistle. Grows to about 8 ft high.
Polemonium caeruleum	Jacob's ladder. (Pupils might want to discuss the biblical reference.) There are many such plants.
Rosa pteracantha	Grown for its huge translucent red thorns.
Salix caerulea	Cricket bat willow.
Tragopogon porrifolius	Salsify. (See figure 67.) Purple flower heads close in the middle of the day. Fine seed parachutes. Edible roots. Is closely related to goat's beard, otherwise called Jack-go-to-bed-at-noon, with similar habits.
York and Lancaster rose	Has striped red and white flowers.

As well as the above, several plants which yield vegetable dyes are suitable for the school garden. Examples are *Berberis* (see page 276), onion, privet, golden rod, *Hypericum*, juniper, broom, and apple and pear bark.

Fig. 67. *Salsify*.
Photo, H. Smith.

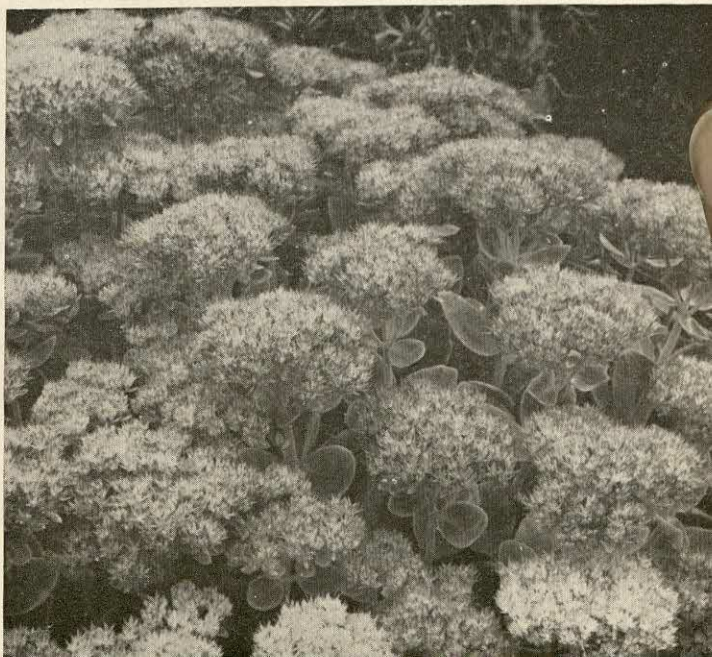


We can also recommend miniature varieties of plants, such as dwarf conifers and miniature roses, as having a special appeal for children.

If children become interested in any plants which fall into a topical group, they may wish to lay out a historical or geographical corner in the garden, or perhaps a part devoted to dyestuffs.

Some plants are particularly attractive to insects and are worth planting for this reason. Notable amongst them is *Buddleia variabilis*, the butterfly bush, which attracts a large number of butterflies and moths. *Sedum spectabile* (figure 68) and Michaelmas daisies also attract a great many insects. Strongly scented plants usually interest children, and a collection of herbs and other aromatic plants such as lavender, rosemary, and cotton lavender might be spared a square yard or two.

Fig. 68. *Sedum spectabile*.
Photo, H. Smith.



Lower plants

ALGAE

A number of water plants are discussed in Chapter 4 (see pages 136-8). Others, less obvious, are worthy of notice. Almost any container of water standing in a sunny window for any length of time will develop a film of green algae. This encourages questions such as the following:

How did they get there? How can we get rid of them?
Can we make them grow more quickly by adding fertilizer?
What is the effect of light? Or temperature?

Experiments are being carried out in various parts of the world to explore the possibility of growing these minute plants in sufficient quantity to make a contribution to the food supply, so they are not to be ignored.

FUNGI: MOULDS AND MILDEWS

Damp bread, stale cheese, boiled cheese, and other foodstuffs, if kept on damp blotting paper under a jam jar, will provide a selection of moulds and mildews of various forms and colours. A bruised apple, pear, or plum will often develop the concentric rings of fructifications of the brown rot fungus, while downy mildew or powdery mildew may develop on classroom plants. In the latter case the growers will have to take some steps to control it. Mould and mildew give rise to such questions as:

Where do they come from?
How fast do they grow? How can we check their growth?

These plants and their allies cause enormous damage by spoiling foodstuffs, rotting wood and other materials, and causing disease in plants. Yet we could not manage without them, for they play an important part in the rotting away of dead plants and animals.

Others have more immediate uses. The veining in cheeses like Gorgonzola is due to a carefully selected strain; penicillin is provided by another. Yeast, so important in the production of wines and beers as well as bread-making, is an allied plant. Its activities in fermentation can be observed in sugar solutions.

Does temperature have any effect?
Does light have any effect?
Will it work in any sugar concentration?

MOSS GARDENS

Mosses tend to be overlooked or regarded as 'just moss'; yet there are hundreds of species in this country which are of considerable interest and beauty when they are observed closely. They will survive indoors if they can be given humid conditions. A moss garden can be made if tufts of a variety of species can be planted on a couple of inches of compost in, say, a leaky old aquarium. The top will have to be covered with a sheet of glass or Polythene to retain atmospheric humidity. When glass sheets are used in this way it is advisable to bind the edges with adhesive tape. This not only renders the sharp edges safe but makes the glass more easily noticed.

FERNS

Growing ferns from spores

This is no more difficult than growing flowering plants from seed, provided that a little care is taken. Packets of fern spores are available from seedsmen, or the spores may be collected from fertile fronds. These can be distinguished by the patterns of brown spore-cases on the back, and they should be collected and hung up in paper bags in a warm dry place until the spores are shed. These form a very fine dark brown dust. They may be sown on compost or sand and peat mixture like seeds. Since they are so small the surface should be very fine and smooth, and it is usual to sterilize the compost if this has not already been done, by pouring boiling water on it and sowing the spores as soon as it is cool. The pot should be enclosed in a Polythene bag, as it is essential that the soil should not dry out. The spores germinate to form tiny green plates called prothalli, and male and female cells must meet in the film of water on these before the young fern plants can be produced. If the sowing is successful the surface of the soil will be covered by a mat of prothalli, and after a time the pale green fronds of the young ferns will arise from these. When these are about half an inch high they should be patched off. This means pricking out, not single plants, but little clumps about as big as a sixpence. These are then grown until the young ferns are big enough to handle. Then the clumps can be split up and the ferns pricked out singly.

Another way of raising ferns is to sow the spores on a piece of porous brick, tile, or flower pot, which is kept moist by being placed in half an inch or so of water. It should be kept covered by an inverted jam jar to retain moisture. A plastic sandwich box is an ideal container for growing ferns in this way.

Some easily cultivated ferns

Asplenium bulbiferum (Spleenwort) POLYPODIACEAE Australia, New Zealand

A fern (figure 55) with much divided dark green fronds, which in well grown plants bear a heavy load of young plantlets. These may be removed and potted up separately when about 3 in. across or a frond or part of a frond may be pegged onto the surface of a pot of soil and the plantlets allowed to root.

Pteris cretica POLYPODIACEAE Tropics and sub-tropics

This is the fern with pale green un-fernlike fronds, divided palmately rather like a lupin leaf, which has so often appeared in butchers' and fishmongers' shops. It is easily propagated from spores, and most of the plants raised from a packet of spores of greenhouse ferns usually turn out to belong to this species.

Harmful plants

Many plants are harmful to us. Some are obviously so, such as the nettles, and thorny or prickly plants. Some cause allergies, such as hay fever (inflicted by pollen), and several induce painful skin conditions in susceptible people. If and when we are affected, we soon learn to treat these plants warily.

While we are quite young, too, we should begin to be aware of the dangers of highly poisonous plants. It is necessary to warn children about these, and especially to make sure they can identify those sources of poison that might appear attractive in some way, such as brightly coloured berries. It is equally important not to over-emphasize the danger so that children become timid in handling plants. Less than half a dozen of our toadstools are really dangerous, but these few are fatally poisonous and we ought to make sure that children know about them. On the other hand it would be ridiculous if children were scared to pick buttercups because they appeared on some list of poisonous plants. They do contain poisons—as do a great many of their family—but nobody is likely to eat enough buttercups to be seriously harmed. In fact, generations of country children have nibbled the seeds to savour the peppery taste. What is important is to make sure children know the really dangerous plants which are widespread.

SOME POISONOUS PLANTS

Amanita muscaria (fly agaric fungus)	Whole plant equally poisonous. (Red cap with white spots.)
Amanita phalloides (death cap fungus)	Whole plant equally poisonous. (Cream-coloured cap.)
Atropa belladonna (deadly nightshade)	Berry (purple and black).
Bryonia dioica (white bryony)	Berry (red).
Conium maculatum (hemlock)	Leaves and seeds.
Hedera helix (ivy)	Berry (black).
Laburnum anagyroides (laburnum)	Seeds.
Ligustrum vulgare (privet)	Berry (black).
Solanum dulcamara (woody nightshade)	Berry (red).
Taxus baccata (yew)	Berry (red) and leaves.

There is one safeguard, as pointed out by an expert: 'Most of the plants which are known to contain the deadliest of poisons also have an unpleasant taste or odour, and because of it they are avoided by human beings and animals alike.'*

Fungi—These are the most harmful group of plants (assuming that we no longer classify bacteria as plants).

1. A few cause animal diseases such as ringworm.
2. Immense losses are caused everywhere by fungal diseases of growing food plants—brown rot of fruits, moulds and mildews on many plants, rusts and other diseases of cereals, and a multitude of more specific diseases such as potato blight, responsible for the potato famine which caused half the population of Ireland in the 1840s to starve or emigrate. Apart from the huge losses caused by such diseases, enormous sums have to be spent each year in preventive measures.
3. The destruction of timber and other materials through fungi such as dry rot also causes great expense.
4. A great deal of food in storage is spoiled by moulds and mildews.

Weeds—By this we mean plants which cause reductions in crops by competing with them for light, water, and nutrients, as well as by acting as hosts for pests and disease-bearing organisms. We have to spend a relatively vast amount of time and money in controlling them, from the small nuisances in the back garden to the world's great infesting weeds such as prickly pear in Queensland, which rendered eleven million acres useless for agriculture, the floating water hyacinth which makes navigation difficult in some African rivers, bramble, again in Australia, and bracken in this country.

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* Forsyth, A. A. (1961) Ministry of Agriculture, Fisheries and Food Bulletin No. 161, *British Poisonous Plants*. H.M.S.O.

Filamentous algae are a nuisance in ponds, and marine algae which foul the bottoms of ships and reduce their speed, are less obvious kinds of weeds.

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